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THE RELATIVE IMPORTANCE OF HEREDITY AND ENVIRONMENT IN THE GROWTH OF PIGS AT DIFFERENT AGES[1]

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Introduction

THE relative importance of heredity and environment in causing differences in weights of pigs has considerable practical importance because of the extent to which rate of gain indicates general health, economy of feed utilization and carcass composition. Information about the heritability of differences is necessary in developing efficient selection indexes and other criteria for breeding more productive swine. If heritability varies from one age to another, this would have an important practical effect on the accuracy of selections made at various ages.

The composition of the gain in weight changes gradually throughout the growing period. For example, growth prior to birth consists largely of structures and organs essential to life processes. The body tissues exhibit marked differential growth behavior after birth, skeleton, muscle and fat developing in that order. The conditions under which growth occurs during prenatal life, in the suckling period and after weaning also differ markedly, so that pigs become more independent of immediate maternal influences as development proceeds. Consequently, it seems reasonable that the extent to which gains are under genetic control may vary according to the circumstances which prevail at a given age. If so, an analysis of the growing period at relatively short intervals should indicate trends of increasing or decreasing importance for heredity, litter environment and environment peculiar to the individual. The present study was intended to throw some light on these trends.

Source of Data

The data were collected from the fall of 1937 through the spring of 1941 at the Nebraska Agricultural Experiment Substation, North Platte, Nebraska. The swine herd at North Platte is maintained as a cooperative breeding project by the Nebraska Agricultural Experiment Station and the

[1] Journal Series No. 305, Nebraska Agricultural Experiment Station in Cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U. S. Department of Agriculture.

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Regional Swine Breeding Laboratory. The herd was composed of six separate lines (from related foundation stock) of purebred Duroc swine in various stages of inbreeding.

The herd was kept under a reasonably uniform system of feeding and management. Shortly before farrowing, each sow was placed in an A-type hog house 7×9 feet in size in individual pens located on clean ground. In some farrowing periods these pens provided green feed; in some, because of weather conditions, little or no green feed was available. The sows and litters remained in these pens until weaning.

After weaning at 56 days, four pigs (usually two barrows and two gilts) from the larger litters were placed in individual pens. In a few cases litters of three pigs were used when it was necessary to use such litters in order to have the desired number of litters from a given inbred line on test.

Each litter was provided with an A-type house for shelter and a small pen. All houses were of the same type and size and although the size of pens varied slightly between seasons, they were uniform in size for any given season. Feeding and watering were as uniform as is possible in practice. The standard concentrate mixture used for test pigs in the Regional Swine Breeding Laboratory was self-fed the pigs from weaning to a final weight of approximately 225 pounds. Weights were taken at birth, 21, 56, 84, 112, 140 and 168 days of age. In cases where pigs reached market weight and were slaughtered before they were 168 days of age, a correction factor based on market weight and age was used to calculate the weight they were expected to attain at 168 days.

The data included 994 pigs representing 259 litters by 62 sires. A few pigs died or were removed before they were 168 days of age because of poor health. The weights of these were not included.

Results

The average weights at the seven ages are given for each of the four fall and four spring farrowing periods in table 1. Although managerial and feeding practices were thought to have been more similar than they are likely to be in the usual swine herd, the average weights in different farrowing periods varied considerably, particularly during the later stages of growth. Table 2 indicates the amounts by which the variance among all pigs could be reduced by excluding the effects of a linear time trend and differences between fall and spring-farrowed pigs. These figures are too small to be of practical importance or to be considered statistically significant.

The proportions of the variances from 56 to 168 days which could be attributed to differences between the four spring or four fall periods are large, indicating that the responsible factors were peculiar to each season (and

TABLE 1.—AVERAGE WEIGHTS AT SEVEN AGES FOR EACH OF EIGHT FARROWING PERIODS

Farrowing period	No. of pigs	Birth	21 days	56 days	84 days	112 days	140 days	168 days
1937 fall	91	2.70	11.5	36.3	64.4	105	147	202
1938 spring	69	2.87	11.7	29.9	56.9	101	143	187
1938 fall	174	2.65	10.6	28.8	53.4	85	120	161
1939 spring	105	2.74	10.5	32.4	58.4	97	136	182
1939 fall	86	2.83	11.1	33.6	65.0	102	143	200
1940 spring	181	2.76	11.6	34.7	66.9	109	156	209
1940 fall	133	2.59	11.0	35.6	68.7	112	162	219
1941 spring	155	2.78	11.5	35.7	61.8	95	135	181
Average	994	2.73	11.2	33.4	62.0	100	142	192
Coefficient of variability		19.7	18.8	19.3	18.4	16.4	15.4	14.4

hence almost certainly environmental in origin). The remainder of the analyses were made on an intraseasonal basis to exclude the effects of seasonal differences. This is in accord with general practice wherein animals born in the same season are usually compared. Since the farrowing period usually lasted 8 to 10 weeks, the time of farrowing within the period may have caused some differences in weight.

Analysis of variance as described by Snedecor (1937) for groups with unequal numbers was used to separate the intraseason variance into portions attributed to three main sources: First, variance caused by factors which influenced all pigs by the same sire but varied from sire to sire; second, variance caused by factors which operated on each litter as a unit independently of sire differences; third, variance due to all the factors which caused litter mates to be unlike.

TABLE 2.—THE PERCENTAGES OF THE VARIANCES AT DIFFERENT AGES ACCOUNTED FOR BY TIME TREND, BY SEASONAL DIFFERENCES AND BY DIFFERENCES BETWEEN PERIODS IN THE SAME SEASON

Age	Linear time trend	Fall vs. spring season	Farrowing periods in same season
Birth	0.0	0.8	0.7
21 days	0.0	0.7	2.7
56 days	0.8	0.3	13.8
84 days	0.8	0.0	17.2
112 days	0.4	0.0	22.0
140 days	0.6	0.0	27.4
168 days	0.7	0.0	32.0

TABLE 3.—ANALYSIS OF VARIANCE FOR WEIGHT AT SEVEN AGES (MEAN SQUARES ONLY)

Source	Degrees of freedom	Birth	21 days	56 days	84 days	112 days	140 days	168 days
Intraseason total	986	.291	4.42	41.7	130.2	269	483	759
Between sires	54	.701	12.15	142.3*	511.4**	1042**	1561**	2566**
Between litters by same sire	197	.706**	10.90**	100.8**	293.0**	556**	967**	1331**
Between litter mates	735	.150	2.12	18.4	58.5	136	274	473

* P = 0.05, significant. ** P = 0.01, highly significant.

The results of the analysis for weight at each of the seven ages are given in table 3. The variance between litters by the same sire was highly significant at each age. The variance between sires (using the mean square between litters by the same sire for error variance) was significant at 56 days and was highly significant at later ages. The influence of the sire may have existed at birth and at 21 days but was so small that significance could be established only by a much larger group of data. Although the intraseason variance in weight increased rapidly with age, the relative variability in weight declined slightly with age, as is indicated by the coefficients of variability given in table 1.

The results of the analysis for gain during each of the six intervals between the seven ages are given in table 4. The variance between litters by the same sire was highly significant for each interval of time. The variance between sires was significant in the second and sixth periods and was highly significant in the third and fourth periods. In the first and fifth intervals where

TABLE 4.—ANALYSIS OF VARIANCE IN GAIN AT SIX INTERVALS (MEAN SQUARES ONLY)

Source	Degrees of freedom	Birth to 21 days	21 to 56 days	56 to 84 days	84 to 112 days	112 to 140 days	140 to 168 days
Intraseason total	986	3.16	26.8	54.3	64.0	67.2	128.1
Between sires	54	9.72	89.4*	176.7**	238.4**	163.9	333.2*
Between litters by same sire	197	8.17**	63.2**	104.3**	107.9**	145.0**	228.5**
Between litter mates	735	1.34	12.2	31.9	39.5	39.2	86.1

* P = 0.05, significant. ** P = 0.01, highly significant.

TABLE 5.—THEORETICAL COMPOSITION OF MEAN SQUARES

Source	Degrees of freedom	Mean square
Intraseason total	986	
Between sires	54	$R+\frac{994}{259}L+\frac{994}{259}\frac{259}{62}S$
Between litters by same sire	197	$R+\frac{994}{259}L$
Between litter mates	735	R

significance was not established the mean square was larger than the appropriate error term, indicating that the effect of the sire may have existed.

In order to examine the importance of the different sources of variation more completely, the mean squares for weight and gain were reduced further as indicated by the theoretical composition of the mean squares in table 5. The mathematical basis for this analysis was given by Winsor and Clarke (1940). The interpretation given the three variances is as follows: The variance expected between pigs in the same litter is designated as R. Two pigs having the same sire but belonging to different litters may differ also in whatever affected one litter but not the other; thus the variance expected among them is R+L. The variance expected for pigs differing in both litter and sire is R+L+S. Values for R, L and S were calculated from the mean squares in tables 3 and 4 and are given for weight in table 6 and for gain in table 7.

The biological significance of the variance from the three sources can be established by considering the genetic and environmental contributions to each of the variances. The percentages of the variance due to gene effects which combine additively represented in R, L and S in a population mated at random are 50, 25, and 25, respectively. The exact distribution of the

TABLE 6.—THE ABSOLUTE VALUES OF R (INTRA-LITTER VARIANCE), L (LITTER EFFECT) AND S (SIRE EFFECT) FOR WEIGHT AT SEVEN AGES

Period	R	L	S	R+L+S
Birth	.150	.145	.000	.295
21 days	2.12	2.29	0.08	4.49
56 days	18.5	21.5	2.6	42.6
84 days	58.5	61.1	13.6	133.2
112 days	136	110	30	276
140 days	274	180	37	491
168 days	473	224	77	774

variance due to dominance deviations and non-additive (epistatic) gene interactions is not clear, but most of the variance from these sources appears in R (Fisher, 1918; Wright, 1935).

Wright (1921) showed that the effect of inbreeding was to increase the genetic variance between lines and to decrease that within lines. In these data, the variance between lines is most nearly represented by that between sires, since only one sire was used in most lines each season. The genetic portion of the variance between litter mates and between litters by the same sire is decreased by inbreeding. According to formulae developed by Dickerson (1941) it appears probable that L contains about 20 per cent of the genetic

TABLE 7.—THE ABSOLUTE VALUES OF R, L AND S FOR GAIN AT SIX INTERVALS

Interval	R	L	S	R+L+S
Birth to 21 days	1.336	1.779	0.097	3.212
21 to 56 days	12.15	13.29	1.64	27.08
56 to 84 days	31.9	18.9	4.5	55.3
84 to 112 days	39.5	17.8	8.1	65.4
112 to 140 days	39.2	27.6	1.2	68.0
140 to 168 days	86.1	37.1	6.5	129.7

variance whereas R and S each contain about 40 per cent in the data from these partially inbred lines.

Clearly, most of the variance in R and L is environmental in origin since both exceed S considerably throughout the growing period. The small size of S at birth and at 21 days indicates that the lines could scarcely have become differentiated in maternal characters such as intra-uterine nourishment or nursing ability. After weaning, treatment was sufficiently standard so that litters by different sires were not purposely treated more or less alike than were litters by the same sire. Accordingly, it is thought that most of S is genetic in origin.

Based on the above premises, the variance (R+L+S) can be separated into portions due to (1) heredity, (2) litter environment and (3) environment peculiar to the individual as follows:

Hereditary portion = 2.5S
Portion due to litter environment = L − 0.5S
Portion due to environment peculiar to the individual = R − S

The portion of the variance due to litter environment is intended to include the effects of all environmental factors which affect all pigs in the litter, whereas that due to environment peculiar to the individual includes the effects of environmental factors which affect individual pigs but not the en-

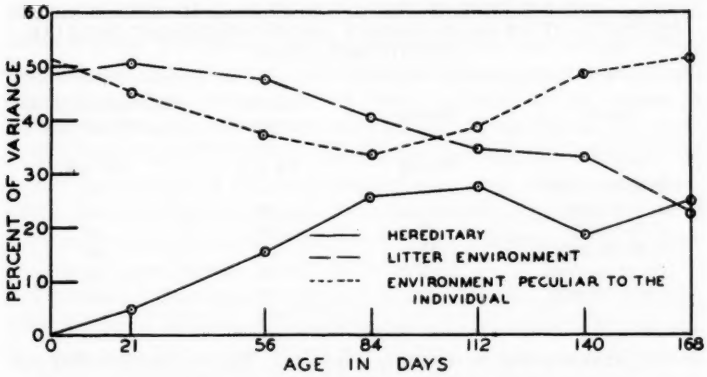

Figure 1. The relative importance of hereditary and environmental variances in determining weight at different ages.

tire litter. For example, variation in the milking ability of dams would contribute to the former source, while variation in the milk flow of mammae on the same udder would contribute to the latter. Values for these three portions (expressed as percentages of the total) are presented in table 8 for weight and in table 9 for gain. Curves were plotted (figures 1 and 2)to show graphically the trends in the relative importance of the hereditary and the two environmental portions of the variance.

From the nature of the assumptions made in estimating the distribution of the genetic variance and the quality of the variance due to sires, the importance of heredity as a source of variance may have been under or overestimated. However, an error due to these sources would introduce an apparently constant bias for all periods so that the *trend* in importance over

TABLE 8.—THE PER CENT OF THE VARIANCE IN WEIGHT ATTRIBUTED TO HEREDITY, LITTER ENVIRONMENT AND ENVIRONMENT PECULIAR TO THE INDIVIDUAL

Age	Heredity	Litter environment	Environment peculiar to the individual
	Per cent	*Per cent*	*Per cent*
Birth	0	49	51
21 days	4	50	46
56 days	15	48	37
84 days	26	40	34
112 days	28	34	38
140 days	19	33	48
168 days	25	24	51

TABLE 9.—THE PER CENT OF THE VARIANCE IN GAIN ATTRIBUTED TO HEREDITY, LITTER ENVIRONMENT AND ENVIRONMENT PECULIAR TO THE INDIVIDUAL

Interval	Heredity	Litter environment	Environment peculiar to the individual
	Per cent	*Per cent*	*Per cent*
Birth to 21 days	7	54	39
21 to 56 days	15	46	39
56 to 84 days	20	30	50
84 to 112 days	31	21	48
112 to 140 days	4	40	56
140 to 168 days	13	26	61

several periods would be relatively unaffected. The one uncontrolled possibility of error which may have affected the apparent trend in the importance of heredity and environment lies in the sampling errors associated with the statistics given in tables 6 and 7. Even such broad classifications in main effects as were used in analyzing the variance from this reasonably large group of data yield statistics not entirely free from sampling error.

The percentages of the variance in 56-day weight due to the three sources (15, 48, and 37 per cent) agree fairly well with those published by Bywaters (18, 40 and 42 per cent). Bywaters (1937) attributed the greater portion of the hereditary variance in weaning weight to non-additive gene interactions,

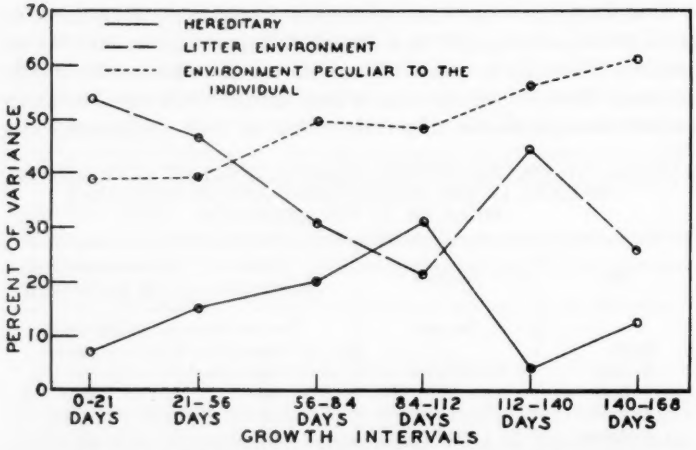

Figure 2. The relative importance of hereditary and environmental variances in determining rate of gain for different intervals during growth.

whereas in this study most of the 15 per cent is believed due to the additive effects of genes. Whatley and Nelson (1942) and Hazel (1941) estimated that the additively genetic portion of the variance in 180-day weight was 23 per cent and 30 per cent, respectively. In this study the hereditary variance in 168-day weight appeared to be about 25 per cent. These figures are in very good agreement in view of the sampling errors involved, especially since the genetic constitution of the herds studied may have differed somewhat. Hetzer (1942) published intraclass correlations which substantiate the trend in the importance of the sire effect after weaning. However, in his data the sire's importance decreased from birth to weaning.

The curves for gain shown in figure 2 are related to the curves for weight given in figure 1, since weight at a given age is the sum of birth weight and the gains made during the intervening periods. In figure 2, environment peculiar to the individual shows a definite trend upward through most of the growing period; whereas the effect of litter environment is definitely downward from birth to 112 days. The hereditary variance becomes increasingly important from birth to the interval from 112 to 140 days. No satisfactory explanation can be advanced for the sharp reversal of trend in the curves for heredity and litter environment during the interval from 112 to 140 days.

Since weight at any age is the sum of weight at the preceding age and gain during the period which intervenes, the curves for weight may be expected to show more regularity than the curves for gain. In figure 1, the curve for environment peculiar to the individual decreases very regularly during the early stages of growth, apparently reaching a minimum at 84 days and increasing thereafter. This curve is in sharp contrast to the corresponding curve for gains (figure 2) because much of the variance in birth weight is due to environment peculiar to the individual. The importance of litter environment decreases from 21 to 168 days. The importance of heredity increases from birth to 112 days. The low heritability of the gain during the interval from 112 to 140 days is reflected in the decrease in importance of heredity in determining weight at 140 days.

Discussion

The idea that the individual's own heredity plays an increasingly important role in development from the time of fertilization until the trait attains full expression is an attractive and seemingly logical genetic theory for many quantitative characteristics. The results indicate that this theory is tenable for weight and rate of gain in swine only from birth to 112 days. Apparently the influence of heredity upon growth before birth is negligible although a high degree of relative variability has been established at birth, of which a large part is not due to intra-uterine environment of the litter as a whole.

The factors which operate to reduce the importance of heredity after 112 days are not clear, but apparently they are associated with the litter as a unit. Spring pigs reached this age in the summer and fall pigs in the winter when conditions were most severe. Since each farrowing season extended over a period of from 8 to 10 weeks, the extreme conditions did not affect all litters at exactly the same age. This suggests the possibility of a close relationship during the intermediate stages of growth between differences due to litter environment and order of birth within the season.

Certain of the environmental trends can be correlated with known managerial practices or environment during development. For example, figure 2 shows a rather definite decrease in the importance of litter environment in determining gain after 56 days, at which time the litters were weaned. There is a corresponding increase in environment peculiar to the individual during the interval following weaning.

From a practical standpoint, the interval of growth immediately preceding 112 days appears to offer greatest opportunity for the identification of animals possessing the heredity for rapid growth rate. If the same genes affect growth for reasonably long periods of time but vary in their importance (during different intervals) as compared to environmental factors, then restricting observations to a short interval when the heritability is high might be as logical a procedure as extending observations to a longer interval where heritability is lower, even if the object were to identify animals having the best genotypes for growth rate from birth or weaning to market age. In addition, a finer subdivision of the growing period has the advantages of permitting earlier identification of choice breeding animals and wider use of the progeny test and family selection.

Since the pigs in this study were descended from related foundation stock, the genetic variance in the first few seasons was probably less than that expected in an average swine population. However, inbreeding within each of the six lines should have caused increased genetic variation during the later periods, unless the genetic divergence between lines was offset by selection within each line for more rapid growth rate. In addition, each litter was grown out in an individual pen, a practice which may have increased the importance of litter environment after weaning, as compared to that expected in a herd where post-weaning treatment was entirely randomized.

Summary

Data on 994 pigs were studied to observe the trends in the relative importance of hereditary and environmental agencies which affect weight and rate of gain from birth to 168 days of age.

Linear time trend over a 4-year period and season of farrowing (spring or

fall) were unimportant sources of variation in weight. The large difference between periods in the same spring or fall season, closely associated with age, indicated that the responsible factors were environmental in origin and peculiar to each season.

The heredity of the pig played an increasingly important role in development from birth to 112 days. The genetic variance in rate of gain during relatively short intervals increased from 7 to 31 per cent. After 112 days the relative importance of heredity decreased considerably.

The relative importance of environment peculiar to the individual in determining rate of gain increased from 39 per cent at birth to 61 per cent at 168 days, the greatest increase being in the interval following weaning.

The relative influence of litter environment in determining rate of gain decreased from birth to 112 days, the greatest decrease being in the interval after weaning. An unaccountable increase occurred during the interval from 112 to 140 days.

The genetic variance in weight increased from zero per cent at birth to 28 per cent at 112 days. After 112 days, a decrease due to the lower heritability of gains in subsequent periods was noted.

The relative influence of environment peculiar to the individual in determining weight decreased from 51 per cent at birth to 34 per cent at 84 days, increasing thereafter to 51 per cent at 168 days.

The relative importance of litter environment in determining weight decreased regularly from 49 per cent at birth to 24 per cent at 168 days.

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STUDIES WITH SWINE ON RATIONS EXTREMELY LOW IN MANGANESE[1]

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JOHNSON (1940) showed that swine grow at a normal rate on a ration containing less than 0.5 ppm. (parts per million) of manganese. In continuation of these studies, further growth records have been obtained, some animals have been carried through reproduction, and several tissue analyses for manganese have been made. The purpose of this paper is to present these observations.

Materials and Methods

The animals were confined indoors, without access to metal of any kind. Special precautions were taken at all times to prevent contamination of the

TABLE 1.—COMPOSITION OF RATIONS

Ration No.	49	50	51	52
Skimmilk powder, lb.	44	44	37	37
Cane sugar, lb.	50	50	47	47
Soybean oil (expeller), lb.[1]	6	6	6	6
"Cerogras" lb.[2]			10	10
Fish liver oil blend, gm.[3]	10	10	10	10
$Fe(NO_3)_3 9H_2O$, gm.	9.04	9.04	9.04	9.04
$CuSO_4\ 5H_2O$, gm.	0.63	0.63	0.63	0.63
$MnSO_4\ H_2O$, gm.		14.80		14.80
Average analysis (moisture free basis)				
Ash, per cent	3.19	3.36	4.07	4.27
Manganese, mg. per kg.	0.27	101.38	6.13	95.36

[1] Kindly supplied by Allied Mills, Inc. through the courtesy of Dr. J. E. Hunter.

[2] Artificially dehydrated young cereal grass, kindly supplied by Cerephyl Laboratories through the courtesy of Dr. W. R. Graham, Jr.

[3] 61,000-A and 21,000-D (USP units per gram), kindly supplied by Mead-Johnson & Co. through the courtesy of Dr. Charles E. Bills.

feed and pens with any foreign matter. The rations were stored in covered galvanized cans, and analyzed from time to time for manganese. Sweet skimmilk was fed with all rations, from 4 to 8 pounds of milk per pound of dry feed, depending on appetite. The milk was taken directly from the creamery in tinned milk cans.

The composition of the dry rations is shown in table 1. Ration 49 is the

[1] Research paper No. 749, Journal Series, University of Arkansas. Published with the approval of the director of the Arkansas Agricultural Experiment Station, Fayetteville, Ark.

chief low-manganese ration used, though some variations were made previous to compounding ration 49. Ration 51, with 10 per cent of "Cerogras," is an attempt to improve ration 49 for reproduction, and rations 50 and 52 are like 49 and 51, respectively, but with 100 ppm. of added manganese.

The average percentages of ash in the dry rations are shown in table 1. The ash may be a factor in the availability of manganese in the feed, as Miller *et al.* (1940) reported that 50 per cent of fattening pigs put on certain rations of natural foodstuffs at 70 to 100 pound weights became stiff at about 150 pound weights, a condition which was prevented, but not cured, by the addition of manganese to the feed. Their basal rations contained 6 to 9 per cent of ash, and 11 to 14 ppm. of manganese.

Manganese was determined by the periodate method (Willard and Greathouse, 1917) with modifications according to Schaible.[2] Repeated analyses of ration 49 have shown 0.23 to 0.30 milligram of manganese per kilogram (ppm.) of oven dry ration. We feel that this ration is as low in manganese content as it is practical to make a ration in quantity which will supply the factors necessary for satisfactory growth of pigs when fed with liquid skimmilk.

A test of ration 49 with chicks was described in the previous report (Johnson, 1940). It showed that manganese is the first limiting factor in this ration for growth of chicks, that it caused a very high incidence of perosis, and that the addition of manganese prevented perosis and secured a reasonable rate of growth.

Results

Growth and Reproduction

The early growth of four littermate sow-pigs on ration 49 plus skimmilk is shown in the top half of table 2. After 98 days on feed, the rations were changed for the reproduction trials as shown in table 3. In the lower half of table 2 are shown the gains of 4 pigs which were born on experiment. Pigs 2, 5, and 8 were born to sow 134 on ration 51, and pig 31 to sow 130 on ration 49. Previous to starting, these pigs were on ration 51 plus skimmilk. During the feeding period they were restricted somewhat in food consumption to prevent the overfatness common to animals on this regime. They did not, therefore, make as great gains as previous animals, but they were large of frame and in good health when slaughtered at the end of the feeding period. In contrast to the findings of Miller *et al.* (1940) lameness or stiffness has not been observed in any of these pigs early in life. Some lameness has usually developed after long periods on ration 49, which has been attributed to infection of the joints arising from foot sores which the large heavy animals

[2] Private communication.

usually developed on concrete floors. Also, erysipelas is present in the Station herd. However, animal 130, which remained on ration 49 throughout life, developed stiffness during early pregnancy without apparent infection. The animal ate well until six weeks before farrowing, and the stiffness did not become severe.

Reproduction on ration 49 has never been satisfactory. One sow was bred at 8½ months of age when she weighed 286 pounds. She was rebred 3 weeks later, and when she succumbed 10 weeks later to an infection of the shoulder

TABLE 2.—GROWTH OF PIGS ON LOW-MANGANESE RATIONS

Animal No.	Ration	Initial age	Duration	Initial weight	Final weight
		days	*days*	*pounds*	*pounds*
130 F	49	36	98	21	130
134 F	49	36	98	21	125
133 F	49	36	98	22	130
131 F	49	36	98	14	123
5 F	49	65	161	37	183
31 F	49	59	161	27	186
8 F	51	65	161	43	184
2 M	51	65	161	46	201

joint, two small mummies were found in the uterus. Another was bred at her first observed estrous,—at 7¾ months and a weight of 266 pounds. She farrowed 2 normal pigs, one alive and the other dead, and she had ample milk at farrowing time though her udder was not fully developed. She refused to let the live pig nurse so it was started on the bottle. This pig made progress for 2 days and appeared out of danger, but it sickened rapidly and died, apparently of pneumonia. The sow was rebred and subsequently farrowed one dead and one weak pig which soon died. The sow had no milk and practically no udder development at the close of this pregnancy. She was killed a week later and one pig was found in the uterus.

Results of the reproduction trials with four littermate pigs on the four rations, table 1, are shown in table 3. These animals were bred at their first observed estrous period, considerably later than the normal time of sexual maturity.

During pregnancy the two sows on the white feeds (49 and 50) gradually lost most of their hair, so that at farrowing time they were almost bald. Their skins were sometimes reddened, dry, a bit scaly, and there was a characteristic odor about these animals. Sow 134, on the low-Mn green ration (51) kept a good hair coat throughout the experiment though it was sometimes curled roughly. Sow 131, which received both the manganese and the

"Cerogras" supplement (ration 52) had a normal smooth glossy hair coat throughout.

Shortly before farrowing all sows except No. 130 had developed full udders from which milk could be easily expressed. The distension of the udders and amount of milk seemed greater for sows 131 and 134 which received the "Cerogras" supplement. All sows except 130 were quiet before

TABLE 3.—GROWTH AND REPRODUCTION OF LITTERMATE PIGS WITHOUT AND WITH MANGANESE AND "CEROGRAS"[1]

Animal No.	Ration		Initial weight	Weight at breeding	Weight at farrowing	Litter record		
						No. of pigs		Weaning weight
	No.	Type				Born	Weaned	
			lbs.	lbs.	lbs.			lbs.
130 F	49	low white	130	284	460	7	2[2]	24.9
134 F	51	low green	125	275	497	8	7[3]	32.5
133 F	50	high white	130	309	533	3	2	34.8
131 F	52	high green	123	285	501	8	0[4]	—

[1] These animals were all on ration 49 from 6 weeks of age.
[2] Sow dry at 11 days, 2 finally raised by hand.
[3] One killed for analysis.
[4] All killed by sow within 3 days.

farrowing and would lay quietly when gently massaged. Sow 130, which had been more or less "off feed" for 6 weeks before farrowing, did not show milk or normal udder distension, and was extremely irritable. She would not allow the massaging along the belly so satisfying to the other sows at this time. This behavior has been a characteristic of the two previous sows which have farrowed while on this ration. There is a lack of appetite, extreme irritability when touched, especially along the belly, and complaint at being driven. It is possible that these symptoms are due to a deficiency of manganese alone.

The two sows on the manganese supplemented rations were extremely vicious toward their pigs at farrowing time. This is often observed among gilts kept in confinement throughout pregnancy but was worse in these animals than ever before encountered by the author. Sow 131, which looked best and had a copious flow of milk, eventually killed all of her pigs. She liked to have them nurse, however, and with care she would unquestionably have accepted all of her pigs in time. Sow 133 would allow the pigs to nurse, and was never excitable, but would watch her opportunity to grab a pig. She eventually bit her two live pigs even though closely guarded. These pigs were kept in a barrel and allowed to nurse every hour or two night and day. After 7 days the sow accepted them, and raised these two pigs unevent-

fully. This is not a good test of ration 50, however, as the sow was large, and did not have a heavy lactation burden. All of the pigs of sow 134, on the low-Mn green ration, grew well and remained sleek. One was killed at 5 davs of age for analysis when it became apparent that none would die. This one successful litter demonstrates that a sow can reproduce successfully on a ration containing only 6 ppm. of manganese.

The history of the litter born to sow 130, which had not gained in weight for six weeks before farrowing, is particularly interesting. These were the only pigs of the four litters which did not appear entirely normal at birth. They were born quite thin and immediately had difficulty getting about. They would shake excessively and walk too stiffly on their toes. Their appetites were good, and they nursed readily without help. At 6 days of age they were getting about almost normally, and were growing and fattening, though the sow appeared to be giving little milk. At this stage one of the pigs was killed for analysis. Shortly thereafter the pigs went down rapidly, the sow dried up by 11 days after farrowing, and two pigs died. The remaining four were taught to drink warm whole cow's milk and at 22 days they appeared sleek, were gaining, and each was consuming 3 pints of milk daily. They sickened at this stage and reduced their milk consumption one-half, and just maintained their weights during the next two weeks. Diarrhoea developed and the pigs frequently vomited. They acted very hungry when fed, but refused to drink much milk. Two pigs died at 31 days of age, still in fair flesh, and acting hungry up to the time of death. Examination showed higher hemoglobin readings for the pigs of this litter than for those of sow 134 which were in excellent health. A small amount of ration 49 had been mixed with the milk for several days but to no avail. One of the pigs had received a dose of 20 grams of dried brewer's yeast in suspension by stomach tube 14 hours before death. One of the two remaining pigs, No. 33, was given a supplement of 25 mgs. of manganese daily, while the other, No. 31, remained as a control. The control pig got better rapidly but relapsed 5 days later, while the pig on manganese supplement remained in poor appetite and with diarrhoea throughout. The afternoon of the 36th day neither would do more than sample the milk, though they continued to act very hungry. Therefore, one-fourth pound of ration 51 was offered, with phenomenal results. This feed was consumed avidly, and within a week the pigs were each consuming one-half pound daily of ration 51. Milk consumption rose rapidly. Two weeks later skimmilk was substituted for whole milk and at 8 weeks of age pig 31 weighed 27.5 and pig 33, 22.2 pounds. Pig 31, which had never received a manganese supplement and had received ration 51 for 3 weeks only, was then placed on the regular routine of a limited ration of skimmilk and ration 49, with results as shown in table 2.

Storage of Manganese in the Body

Manganese analyses of the livers, kidneys, and femurs of the experimental animals have been made. The content of manganese in the kidneys has been more variable, and usually slightly lower, than the figures for the livers. Most of the manganese of the femurs has been found in the shafts of the bones. Since the manganese content of the livers has been most uniform and

TABLE 4.—MANGANESE CONTENT OF LIVERS OF SWINE

Animal No.	Ration No.	Time on ration	Age of animal	Body weight	Mn in dried liver	
					mgs./kg.	Total
		months	*months*	*kgs.*	*mgs./kg.*	*mgs.*
14 F	49	5½	5½	84.35	2.19	3.11
121 M	Standard[1]	1¾	3¼	35.83	10.00	2.91
120 F	49	1¾	3¼	32.65	4.19	1.25
124 F	49	15	16½	238.14	1.81	1.17
122 F	50	4	11	125.17	6.44	3.85
110 M	49	2¾	3¾	55.78	5.67	2.07
112 M	49	2¾	3¾	53.97	2.70	1.22
111 M	50	2¾	3¾	58.96	15.93	6.64
113 M	50	2¾	3¾	42.18	15.09	5.28
3 M	51	3½	3½	27.67	6.96	1.69
22 F	50	3½	3½	30.39	7.11	1.89
132 M	Control[2]		1¼	12.56	10.05	0.76
135 M	Control[2]		1¼	10.25	9.47	0.62
130 F	49	12½	13½	176.90	0.93	0.41
134 F	51	14¼	15½	195.96	1.98	1.04
133 F	50	14¼	15½	220.00	4.27	1.96
131 F	52	12½	13¾	187.79	7.09	3.51

[1] 121 M was on pasture, self fed corn and tankage, and was killed as a check to its experimental littermate, 120 F.
[2] The dam of these pigs received corn and skimmilk, and these two controls were killed for analysis when their 4 littermates were started on experiment.

most sensitive to change in manganese intake, the liver analyses are selected for presentation. Results are given by litters in table 4. The general trend is toward a lower content of manganese per unit weight of liver with increasing age even for animals on the high-Mn ration. This is especially true for animals on the low-Mn ration No. 49. Thus pigs 110 M, 112 M, and 120 F were all under 4 months of age, and the dried livers analyzed 2.70 to 5.67 mgs. of manganese per kg., while the liver of the 5½-month old pig 14 F showed 2.19 mgs. per kg. The livers of the relatively matured animals 124 F and 130 F contained only 1.81 and 0.93 mgs. of manganese per kg., respectively.

In order to compare the effects of a normal swine feeding routine with that of ration 49, the liver of pig 121 M was analyzed at the same time as that of its littermate, 120 F. The former had been handled normally on pasture and a self-feeder for the 7 weeks since weaning while the latter had been on ration 49. The manganese content of the liver was reduced one-half of normal by the feeding of ration 49 for this period.

The next litter compares the effects of the high and low-manganese rations. Ration 50 brought about 3 to 4 times as much manganese storage in the livers as did ration 49.

TABLE 5.—MANGANESE CONTENT OF LIVERS AND WHOLE BODIES OF SMALL PIGS

Pig No.	Dam No.	Ration No.	Age	Body weight	Mn in dried liver		Mn in dried body[1]	Total Mn in body
					mgs./kg.	total		
			days	*kgs.*		*mgs.*	*mgs./kg.*	*mgs.*
In uterus	124	49	0	0.60			0.98	0.13
F	124	49	2	0.60	4.02	.014	1.40	0.19
M	124	49	0	0.76	2.12	.007	1.43	0.21
35 M	130	49	6	1.30	3.89	.036	0.63	0.21
2 M	130	49	31	2.27	2.41	.060	0.33	0.25
36 M	130	49	31	2.77	1.68	.046	0.56	0.47
4 M	134	51	5	1.90	3.64	.060	0.91	0.42
23 F	133	50	0	1.36	7.13	.068	5.70	1.42
14 M	131	52	0	1.43	8.86	.084	4.99	1.37
15 F	131	52	0	1.21	13.77	.100	5.63	1.29

[1] Exclusive of liver.

Of the last litter in table 4, only one animal, No. 130, showed a reduction in total manganese content under that found in the controls at the beginning, though percentage content was reduced in all, due to increasing age. The value of 0.93 mgs. of manganese per kg. of dry liver of sow 130 is the lowest obtained in this work. The total amount of 0.41 mgs. of manganese in the liver of this sow, while very low, is not more than one-half of the daily intake of manganese by this sow during pregnancy even though she had been on ration 49 since very early in life.

In table 5, the manganese content of the livers and whole bodies of pigs, exclusive of contents of the digestive tract, are shown. New-born pigs had a higher level of manganese in their liver tissue than did their dams. Newborn or young pigs of sows on ration 49 had a total of 0.13 to 0.21 mg. of manga-

nese in their bodies. One pig of sow 134, on ration 51, contained 0.42 mgs. while the bodies of pigs from sows on the high manganese rations contained 1.29 to 1.42 mgs. of manganese.

Contrary to expectations, it has been extremely difficult to produce clear cut manganese deficiency in swine with the methods employed. Stiffness has frequently occurred at about 300-pound weights or larger, some of which may be due to manganese deficiency. The irritability observed in late pregnancy of sows on ration 49 quite possibly is due to manganese deficiency. The thin hair coat and reddened skin are tentatively attributed to a lack of some factor other than manganese which green feed supplies. A deficiency of manganese may be responsible for the partial debility shown by pigs born to sows on ration 49, but all individuals of one litter of these pigs survived for some days and gained in weight. A green feed supplement to cow's milk was eventually necessary to raise any of these pigs. The observations to date do not indicate definitely whether manganese deficiency or a lack of some factor in green feed is responsible for the inferior udder development of sows on ration 49.

In view of the special methods necessary to materially reduce the storage of manganese in the body and to develop symptoms of deficiency, it appears unlikely that a deficiency of manganese occurs in normal practice. When there is access to soil, grass, iron rust, oats, bran, shorts, or other feeds containing an appreciable amount of manganese, a pig may easily consume each day as much or more manganese than is stored in its liver or even in its entire body.

Summary

Growing pigs throve on a ration containing less than ½ part per million of manganese which produces a high incidence of perosis in chicks. Reproduction on this ration was unsuccessful, but when a green feed supplement ("Cerogras") was added to the ration, which raised the manganese content in the dry feed to 6 ppm., reproduction was satisfactory.

The dried livers of animals on the high manganese rations contained 4 to 15 ppm. of manganese while those of animals on the low manganese ration contained 1 to 6 ppm. The lower figures in each case were found for the older animals. Pigs born to sows on rations containing 100 ppm. of manganese contained 1.29 to 1.42 milligrams of manganese in their bodies. One pig of a litter born to a sow on the ration containing 6 ppm. of manganese contained 0.42 milligram of manganese, the littermates were raised uneventfully. Pigs born to sows on the ration which contained less than ½ ppm. of manganese contained 0.13 to 0.21 mgs. of manganese, and some littermates to these pigs were raised successfully.

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THE MINIMUM REQUIREMENT OF NICOTINIC ACID FOR THE GROWING PIG

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Introduction

CHICK and co-workers (1938), Hughes (1938), Madison *et al.* (1939), Wintrobe (1939), and Davis and colleagues (1940) have shown that nicotinic acid is necessary in the proper nutrition of the young pig. The minimum requirement of this factor has not been reported for the pig. In highly purified diets, 15 mg. of nicotinic acid per 100 pounds of pig daily has usually been fed at this station with satisfactory results. Because the need might be less than this, it was decided in 1941 to determine, if possible, the minimum requirement of this factor for growing swine.

Experimental

In the summer of 1941, an experiment was conducted with 5 groups of pigs with 5 in each. Nicotinic acid was fed in varying amounts from 0 to 25 mg. per 100 pounds of pig daily. There was practically no difference in the gains or condition of any of the groups. Because it was known that this factor was necessary in the diet of growing pigs, these results were surprising. The pigs on the basal ration and on the lower levels of nicotinic acid licked the floors, which led to the supposition that possibly molds and yeasts were synthesizing this factor on it. Molds and yeasts were found in large numbers on the floors and presumably nicotinic acid was being synthesized because the results of a later experiment were positive. The pen floors were thoroughly cleaned, using a wetting powder and a strong lye solution, after which a thin coating of fine sand and cement was applied to the cleaned pens before the second experiment began. The floors were thoroughly cleaned 3 times each week (using a wetting powder and strong lye solution) throughout the winter experiment. (A more complete discussion of the methods used to determine the mold and yeast populations appears in another paper (Hughes and Squibb, 1942).)

The second experiment began December 2, 1941, and closed February 17, 1942. The following diets were used:

Lot 1—Basal ration, composed of beet sugar 81%, purified casein 15%, salt mixture 4%, cod liver oil 10 cc. per head weekly, thiamin 3 mg., riboflavin 4.5 mg., pantothenic acid 10 mg., pyridoxine 5 mg., per 100 pounds of pig daily.

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Lot 2—Basal + 5 mg. nicotinic acid per 100 pounds of pig daily.

Lot 3—Basal + 10 mg. nicotinic acid per 100 pounds of pig daily.

Lot 4—Basal + 15 mg. nicotinic acid per 100 pounds of pig daily. The salt mixture was the same as that described in another paper (Hughes, 1942).

Results

The results of the second experiment are summarized in table 1 and figure 1. The pigs fed the basal and those fed 5 mg. per 100 pounds of pig daily

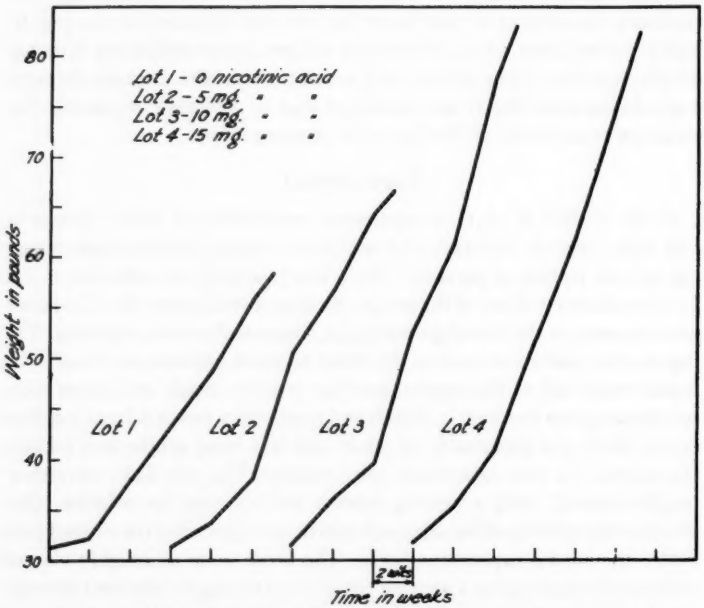

Figure 1. Growth curves of pigs fed varying amounts of nicotinic acid.

gained more slowly than those given larger quantities of nictotinic acid. Those fed higher levels (lots 3 and 4) also consumed less feed for a pound of gain.

There was some variation in the rate of gain within the various lots. The greatest variation was in the lots fed 0 and 5 mg. of nicotinic acid. When the daily gains of pigs in lots 2 and 3 were compared it was found that one pig (heaviest in the lot) given 5 mg. of nicotinic acid gained slightly faster than the slowest pig (lightest in the lot) fed 10 mg. Otherwise each of the pigs fed 10 mg. gained faster than those given 5 mg. per 100 pounds of pig daily.

Before the end of the 3rd week of the experiment, 2 pigs were unable to arise. One was in lot 1, the other in lot 2. A week later another pig in lot 2 was down and the other crippled pig had died. At autopsy, this pig was described as being thin, and emaciated with most of the internal organs normal. There was some sand in the small intestine.

By January 15, 1942, all the pigs in lots 1 and 2 were unsteady on their feet, they appeared less vigorous and their daily food consumption was less than those of the other groups. The crippled pig in pen 1 became very thin

TABLE 1.—RATE OF GROWTH, FEED REQUIREMENTS AND OTHER INFORMATION CONCERNING THE EXPERIMENT*

Lot No.	Ration fed	Average initial weight (pounds)	Average daily gain (pounds)	Feed required for 100 pounds gain (pounds)
1	Basal	31.2	.36	372
2	Basal+5 mg.**	31.2	.43	348
3	Basal+10 mg.**	31.2	.68	255
4	Basal+15 mg.**	31.2	.67	262

* There were 5 pigs in each lot and they were on the experiment 77 days.
** Per 100 pounds of pig daily.

and was unable to arise. On January 23, he was given nicotinic acid in solution. This was continued until the end of the experiment. In about 10 days he was able to get up and walk around. In a month's time, he had recovered and looked normal and thrifty. Another pig in lot I died the last day of the experiment. A large hair ball was found in his stomach, and there was some inflammation in the stomach and bladder.

The first signs of a deficiency in the pigs in lots 1 and 2 was a loss of appetite, and some individuals vomited. Each pig in lot 1 and most of the pigs in lot 2 scoured some. The hair and skin of all the pigs in both these lots (except 1 individual in lot 2) were dry and harsh. There was no evidence, however, of the skin condition as described by Chick *et al.* (1938). No one has previously reported that pigs on a nicotinic acid deficient diet would go down and be unable to arise. Paresis and spasticity of the muscles of the hind quarters was reported by Chick *et al.* (1938).

At the close of the experiment the 3 pigs left in lot 1 were given an adequate amount of nicotinic acid which resulted in an immediate increase in food consumption, rate of gain and an improvement in physical well being.

Nothing unusual happened to the pigs in lots 3 and 4. They gained more rapidly, were more uniform in appearance, were more active and thrifty throughout the experiment than those of lots 1 and 2.

Summary

That nicotinic acid is necessary in the nutrition of the pig has been confirmed.

From the results of these studies, apparently the requirement of nicotinic acid for young growing swine lies between 5 and 10 mg. per 100 pounds of pig daily.

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THE USE OF COTTONSEED MEAL IN THE RATION OF PREGNANT EWES[1]

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IT IS a common opinion among sheepmen that amounts of cottonseed meal in excess of .25 lb. per head daily are not safe in feeding pregnant ewes. Perhaps this idea is founded upon a one-year experiment at the Oklahoma Experiment Station conducted twenty-four years ago (Russel, 1919). In this experiment two lots of twenty ewes each were subjected to a low plane of nutrition and fed .5 lb. of cottonseed meal per head daily. They were confined in a small lot and received little exercise. A few of the ewes became sick, some died, and one aborted; it was concluded that the trouble resulted from the feeding of the cottonseed meal. A careful study of the described symptoms leads one to conclude that the trouble may well have been what is commonly referred to today as "Pregnant Ewe Disease." The ewes died too suddenly after becoming noticeably sick to suspicion trouble from vitamin A deficiency.

Gray and Ridgway (1909) had earlier fed 65 head of ewes on varying amounts of cottonseed meal during a three-year period. Some of their ewes received as much as .5 lb. or over for a 200 day period when cottonseed hulls were used as the only roughage. Six abortions resulted in ewes on the experimental rations, but this number was not in excess of those occurring in the check group.

Large amounts of cottonseed meal have been fed to ruminants with satisfactory results. Briggs (1941) has fed fattening lambs an average of .80 lb. of cottonseed meal through an entire feeding period and during certain portions of the feeding period, the lambs have consumed in excess of 1.0 lb. per day with safety. Kuhlman, *et al.* (1936) have successfully fed dairy calves from weaning through a lifetime of production with cottonseed meal as the sole concentrate. High levels of cottonseed meal were therefore fed through repeated pregnancies without adverse results.

Procedure

In the fall of 1939 an experiment was started at the Oklahoma Experiment Station to study the toxicity of cottonseed meal for pregnant ewes when fed in excess of the amount needed to balance the ration. Forty grade Rambouillet or western ewes and twenty purebred Hampshires were used in each of

[1] Read at the American Chemical Society Meetings, Memphis, Tennessee, April 22, 1942.

[2] Stillwater, Oklahoma.

three years. The two kinds of ewes were used because of the difference in size and body weight and each represented an extreme in these respects of ewes generally used in commercial production. Each lot consisted of ten ewes and all ewes were bred to purebred Hampshire rams.

First Experiment

In the first experiment the ewes received the experimental rations indicated in table 1. Experimental feeding started November 10, 1939, and continued until all pregnant ewes had lambed. Weights of ewes were not taken after December 30 because the ewes were getting heavy in lamb and the first ewe lambed January 3, 1940. Most of the western ewes had lambed by January 20, but those that had not were placed together and fed a ration consisting of .5 lb. cottonseed meal and 2.5 lbs. prairie hay. Lots I and II, which consisted of Hampshire ewes, were fed separately until all ewes in each lot had lambed.

Second Experiment

The second experiment was conducted in a similar manner except that experimental feeding was started on October 16, 1940, for the western ewes and of November 26, 1940, for the Hampshires; the rations fed are given in table 1. Body weights were not taken after November 30 for the westerns and January 9 for the Hampshires. On the latter date the Hampshire ewes were placed together and fed a ration consisting of .2 lb. oats, .5 lb. cottonseed meal and 4.0 lbs. alfalfa hay until all pregnant ewes had lambed.

Third Experiment

The third experiment was started on October 10, 1941, for the western ewes and on November 6, 1941, for the Hampshire ewes. Body weights of the ewes were not taken after December 6, 1941, and January 3, 1942, respectively, because the ewes were approaching their lambing dates. The first western ewe lambed December 11. The experimental feeding of each lot was continued until January 5; from that date until all ewes had lambed, the ration of lot VI or .5 lb. cottonseed meal and 2.8 lbs. prairie hay was fed to the ewes that had not yet lambed. The last western ewe lambed on January 15. The first Hampshire ewe lambed January 9, and all ewes in both lots were fed their respective rations until lambing was completed.

Carotene Determinations[3]

The carotene content of the feeds was not determined the first year, but in the second experiment, the prairie hay fed contained 18.7 p.p.m. and the

[3] Carotene determinations were made by Dr. W. D. Gallup of the Agricultural Chemistry Department.

TABLE 1.—RATIONS AND AVERAGE DAILY GAIN OF EXPERIMENTAL EWES

Experiment No. and type of ewes used	Lot No.	Oats	Cottonseed meal	Alfalfa hay	Prairie hay[1]	Ave. daily gain[2]
		pounds	*pounds*	*pounds*	*pounds*	*pounds*
Experiment I						
Hampshires	I	.39	.25	3.11	—	.12
Hampshires	II	.06	.50	3.11	—	.13
Westerns	III	.25	.25	3.10	—	.24
Westerns	IV	.14	.50	3.10	—	.32
Westerns	V	.40	.25	—	2.39	.20
Westerns	VI	.15	.50	—	2.39	.13
Experiment II						
Hampshires	I	.11	.25	4.00	—	.29
Hampshires	II	—	.50	4.00	—	.31
Westerns	III	.25	.25	2.70	—	.39
Westerns	IV	.08	.50	2.70	—	.38
Westerns	V	.41	.25	—	2.70	.28
Westerns	VI	.16	.50	—	2.70	.33
Experiment III						
Hampshires	I	.25	.25	4.00	—	.42
Hampshires	II	.06	.50	4.00	—	.51
Westerns	III	.25	.25	2.80	—	.37
Westerns	IV	.13	.50	2.80	—	.33
Westerns	V	.43	.25	—	2.80	.31
Westerns	VI	—	.50	—	2.80	.36

[1] All ewes receiving prairie hay received .25 oz. finely ground limestone per head daily in the concentrate mixture.
[2] Prior to time first ewes started to lamb.

alfalfa hay 30.0 p.p.m. of carotene. A carotene analysis for the third experiment showed the alfalfa hay to contain 13.6 p.p.m. and the prairie hay 4.6 p.p.m. The cottonseed meal and oats contained none. Oats was chosen as the experimental grain because of its being devoid of carotene. Increasing or decreasing the amount of grain to keep the various lots of ewes gaining at the desired rate was accomplished without changing the carotene intake.

Results and Discussion

The rations that were fed and the body gains resulting from these rations are given in table 1. In the first experiment the ewes failed to clean up as much prairie hay as was desired. During the second and third experiments this hay seemed more palatable and the two hays were fed the western ewes at the same level. All ewes appeared in good thrift on their respective rations and were in good flesh at the time of parturition.

TABLE 2.—THE LAMBING RECORD OF EWES RECEIVING DIFFERENT LEVELS OF COTTONSEED MEAL

Experiment No. and type of ewes used	Lot No.	Pounds of c.s.m. per head daily	No. of ewes		No. of lambs born				Ave. birth weights	
			completing trial	lambing	Total	Vigorous	Weak	Dead at birth	Single	Twins
Experiment I										
Hampshire	I[1]	.25	9	9	14	11	1	2	10.3	9.1
Hampshire	II	.50	10	10	18	14	1	3	10.7	8.7[2]
Western	III	.25	10	9	11	11	0	0	10.4	7.4
Western	IV	.50	10	7	8	7	0	1	11.1	8.0
Western	V	.25	10	9	11	11	0	0	10.4	7.4
Western	VI	.50	10	10	10	9	0	1	10.7	—
Experiment II										
Hampshire	I	.25	10	9	10	9	0	1	9.8	7.1
Hampshire	II	.50	10	7	10	10	0	0	10.6	10.2
Western	III	.25	10	10	14	14	0	0	10.6	9.2
Western	IV[3]	.50	9	9	10	10	0	0	11.0	9.5
Western	V	.25	10	10	10	10	0	0	10.6	—
Western	VI	.50	10	10	13	11	2	0	9.5	7.9
Experiment III										
Hampshire	I	.25	10	10	12	10	1	1	9.0	7.7
Hampshire	II[4]	.50	9	6	11	11	0	0	12.4	8.7
Western	III	.25	10	10	14	14	0	0	10.8	8.5
Western	IV	.50	10	10	13	13	0	0	11.5	9.1
Western	V	.25	10	10	12	11	1	0	10.3	9.0
Western	VI	.50	10	10	12	9	1	2	10.0	9.8

[1] Nine ewes finished the trial, one died following broken jaw.

[2] Includes one set of triplets averaging 8.0 lbs. each.

[3] One ewe came in heat early in the experimental feeding period and was removed from the lot.

[4] One ewe died February 14, 1942, of chronic heart and lung condition. She was not pregnant.

The lambing record of the ewes is shown in table 2. Ten ewes were the original number in each lot.

Only one lamb was born prematurely during the three years of the experiment. A Hampshire ewe in lot I aborted in the spring of 1941 from an unknown cause. She was in good flesh in apparent good health, and there were no indications of injury. No ewes showed any signs of ill health during the time they were on experimental rations, except one ewe that had a broken jaw, and in several instances ewes were on the rations longer than the entire gestation period. These results indicate that no harmful effects should be expected in feeding pregnant ewes as much as .5 lb. of cottonseed meal per day. Such large allowances of concentrate are seldom needed in commercial

production, except in late pregnancy, if adequate roughage is supplied. It thus appears that cottonseed meal can be used as the only concentrate if such feeding is economical although .25 lb. is adequate to supplement the ration of pregnant ewes receiving even non-legume roughage.

The smallest intake of carotene in the last two years was in lots V and VI in the third experiment. The estimated intake of these ewes at their peak weight was 83.5 micrograms per kilo of live weight or approximately 38 micrograms per pound. This is about three times the required amount found needed by Guilbert and others (1937) at the California station for the maintenance of the various farm animals. Hart and Miller (1937) have shown that ewes with normal storage of vitamin A at conception can be carried through pregnancy on a diet very low in vitamin A. The ewes in this study should have had a normal storage at the beginning of each season because they ran on pasture until they were confined in dry lot at the start of experimental feeding.

The ewes were weighed at regular intervals and the amount of oats was regulated to keep the ewes in the various lots thrifty and gaining approximately the same. This later aim was not always achieved because of rapid weight increases that would occur near the latter part of the period in the ewes about ready to lamb. The same amount of cottonseed meal was fed during the entire period. The hay was always limited in quantity so that it would be cleaned up before the next feed.

Considerable variation existed in the lambing of the different lots. No doubt this is due to the small number of ewes in each lot and that some ewes failed to conceive. The ewes appeared very thrifty, lambed with ordinary labor, and milked well following parturition.

Summary

No abortions were experienced during three winters in which pregnant ewes were fed a .5 lb. level of cottonseed meal during the gestation period. Very similar results were secured in rations containing .25 and .5 lb. of cottonseed meal with either alfalfa or prairie hay. Prairie hay properly supplemented with cottonseed meal and finely ground limestone gave results very similar to those obtained with alfalfa hay except during one year when prairie hay was quite unpalatable. The minimum level of carotene fed was 38.0 micrograms per pound of body weight and proved adequate for a normal pregnancy.

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STAPLE LENGTH IN RELATION TO WOOL PRODUCTION

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STAPLE length is one of the important characteristics in determining the wool value of breeding sheep since it influences the price as well as the amount of clean wool that is in a fleece. Within a grade, length of staple affects returns to the producer to the extent that wool measuring two inches or over in length now brings from 2 to 7 cents more per pound of clean wool than wool measuring less than 1.4 inches.

Length of staple is important to wool buyers, dealers, and manufacturers since it is a factor in estimating the amount of clean wool and determining whether the wool is to be used for woolen or worsted manufacture. It is especially important to the manufacturer of fine worsted material since this type of manufacture depends on wool top in which fibers are long and strong enough for the carding and combing operations. Since length is so important to the wool manufacturers it is desirable that producers know the average grade and shrinkage of their wool, and the relationship that exists between length of staple and the amount of clean wool produced. A knowledge of these points enables the producers to better evaluate their wool and to have a more complete understanding of wool improvement through breeding.

Wilson (1942) points out that good breeders in Australia and New Zealand have been stimulated to learn what constitutes good fleece characteristics. Hill[3] stated that, "Length is very important. If the wool is short, the fleece will be small, and if it is not long enough to be graded as combing wool, the value per pound is decreased." Neale *et al.* (1941) shows the effect and value of fleece length in a sheep and wool improvement program. American breeders could be expected to make more progress if they had more complete information concerning the productive ability of the animals. Some studies have been made on the relationship of length of staple to wool production. Spencer *et al.* (1928) found a high correlation between length and clean weight of fleece but this was low for length and unscoured fleece. Duerden *et al.* (1932) found a low correlation between the weight of fleece and length of fibers in Merino wool. Terrill[4] found a high correlation between fleece length and weight of both the unscoured and the scoured fleece. Cooper and Stoehr (1934) pointed out that there is apparently a high correlation within breeds between fleece weight and fleece length.

[1] Acknowledgment is made to Clair E. Terrill for his assistance in the study.

[2] Western Sheep Breeding Laboratory, Dubois, Idaho.

[3] Hill, J. A., Selecting Range Ewes for More and Better Wool. Talk presented before the Idaho Wool Growers' Assoc., Boise, Idaho, Jan. 4 and 6, 1940.

[4] Terrill, Clair E. Unpublished data.

The present study was undertaken to obtain more comprehensive information on the subject. Four breeds of sheep have been used in order to include most of the common commercial grades. These grades, as designated by the American and English systems, are tabulated below along with the length requirements for combing wool:

Grade		Commonly accepted length requirements for combing wool	
American	*English*	*Inches*	*Cm.*
Fine	80's, 70's, 64's	2	5.0 and longer
Half-Blood	62's, 60's, 58's	2½–3	6.4 and longer
Three-eighths Blood	56's	3½	9.0 and longer
Quarter Blood	50's, 48's	4	10.2 and longer
Low-Quarter Blood	46's	5	12.7 and longer
Common	44's	5	12.7 and longer
Braid	40's, 36's	5	12.7 and longer

Body weight has also been studied in relation to staple length and wool production in order to make the study more complete from the standpoint of the practical wool grower.

Material and Methods

A total of 983 yearling ewes, consisting of 206 Rambouillet, 281 Targhee, 251 Columbia, and 245 Corriedales were used in this study from the flocks of the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory at Dubois, Idaho, from 1938–41 inclusive. The average birth date for the Rambouillet yearling ewes was May 10 in 1937–38 and April 7 in 1939–40. The Targhee, Columbia and Corriedale average birth date was April 7, in 1937–38, and April 23 in 1939–40. Thus, the Rambouillet ewes were approximately one month older the last two years before shearing, and the Targhee, Columbia and Corriedale ewes were about 2 weeks younger the last two years. The average day's fleece growth before shearing for the Rambouillet lambs born on or about May 10 was 386 days, and 418 days for those born about April 7. The average for the other three breeds born about April 7 was 418 days, and 411 for those born about April 23. This change was occasioned by management practice.

Wool samples and length measurements were taken on each individual animal from the middle of the right side during the latter part of May, just prior to shearing. The sample areas were sheared with an electric clipper (shearmaster) and averaged approximately 5.2 centimeters (2 inches) wide and 11.0 centimeters (4⅓ inches) long. This area yielded from 25 to 35 grams of wool that was immediately placed in a moisture-proof container until it was scoured. These samples were scoured by the usual laboratory wool

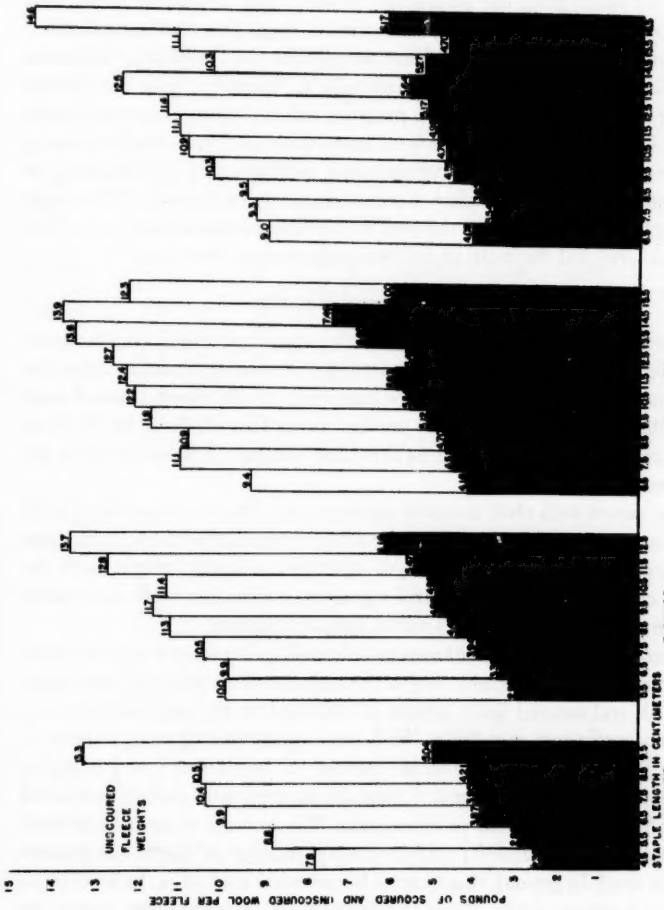

Figure 1. Length of staple in relation to scoured and unscoured weight of fleece. Basic data are shown in table 1.

scouring "emulsion process," and results were used as the clean yield percentage determinations on a bone dry basis. Bone dry, clean wool yields may be converted to commercial yields by dividing the bone dry percentage by 0.88; the result gives the percentage of clean wool containing 12 per cent moisture. It has been shown by Schott *et al.* (1942) that small samples overestimate clean yield and clean fleece weights for the Corriedale, Columbia and Targhee breeds but not for Rambouillets. Therefore, these data should not be used for breed comparison purposes unless the proper corrections are made. Unscoured fleece weights were recorded as the fleeces came from sheep on the shearing floor. The percentage clean yield was used in calculating the total amount of bone dry clean wool produced by each animal. The length of staple was measured to the nearest 0.2 centimeter at each end of the sampled area and the mean of the two measurements was used.

Discussion of Results

Changes in wool production with increasing staple length are illustrated in table 1, and figure 1. These show averages for wool production within the various ranges of staple length. The commercial grade classification of wool from the four breeds studied was predominantly Fine (64–80's) for the Rambouillet; ½ Blood and Fine (60–64's) for the Targhee; ⅜ Blood (56's) for the Corriedale.

The means with their standard deviation and determinations for each of the four breeds of sheep are shown in table 2, together with the correlation and regression coefficients of length of staple and body weight with the other characters. Correlation and regression coefficients were determined within years to exclude effects due to annual variations.

There is a significant within-year relationship between length of staple and unscoured fleece weight, length of staple and clean yield and also length of staple and scoured fleece weight as indicated by the regression and correlation coefficients in table 2. With each centimeter (⅜ inch) increase in staple length there was an average increase of from about ½ to ¾ pound of unscoured wool, ¼ to ½ pound of bone dry scoured wool and an increase of from .85 to 2.52 per cent in clean yield. The increase in scoured and unscoured weight of fleece for each centimeter increase in length was greatest for fine wool. In general, this increase becomes less marked as the wool tends toward a coarser grade. Fleece density also influences to some degree the greater clean wool increase for finer wools.

Length of staple had a higher relationship with clean fleece weight than with any other characteristic studied in each of the four breeds. From 12 to 21 per cent of the variation in clean fleece weight was explained by or associated with variation in length.

TABLE 1.—AVERAGES FOR WOOL CHARACTERS AND BODY WEIGHT WITHIN STAPLE LENGTH GROUPS

Breed	Staple length range	No. ewes	Staple length mean	Unscoured fleece weight	Clean* yield	Scoured* fleece weight	Body weight after shearing
	cm.		*cm.*	*lbs.*	*per cent*	*lbs.*	*lbs.*
Rambouillet	4.0– 4.9	10	4.74	7.8	30.1	2.35	77
	5.0– 5.9	41	5.47	8.8	33.0	2.89	78
	6.0– 6.9	79	6.45	9.9	35.6	3.87	93
	7.0– 7.9	62	7.37	10.4	38.0	3.95	82
	8.0– 8.9	10	8.18	10.5	40.1	4.21	81
	9.0– 9.9	4	9.33	13.3	38.0	5.04	98
All ewes		206	6.59	9.8	35.8	3.52	81
Targhee	5.0– 5.9	4	5.80	10.0	29.9	2.92	87
	6.0– 6.9	28	6.53	9.9	34.3	3.38	87
	7.0– 7.9	72	7.46	10.5	37.6	3.94	88
	8.0– 8.9	83	8.38	11.3	39.5	4.43	91
	9.0– 9.9	46	9.41	11.7	41.8	4.86	92
	10.0–10.9	27	10.34	11.4	43.6	4.92	94
	11.0–11.9	15	11.33	12.8	43.7	5.47	96
	12.0–12.9	6	12.52	13.7	44.8	6.14	98
All ewes		281	8.53	11.1	39.5	4.39	90
Columbia	6.0– 6.9	3	6.6	9.4	44.2	4.16	94
	7.0– 7.9	17	7.6	11.1	41.0	4.51	99
	8.0– 8.9	42	8.6	10.9	40.8	4.70	99
	9.0– 9.9	74	9.4	11.8	43.7	5.12	99
	10.0–10.9	60	10.3	12.2	42.3	5.54	102
	11.0–11.9	36	11.4	12.4	47.8	5.93	105
	12.0–12.9	7	12.2	12.7	43.9	5.49	102
	13.0–13.9	7	13.3	13.6	49.2	6.65	107
	14.0–14.9	4	14.2	13.9	54.0	7.49	117
	15.0–15.9	1	15.0	12.3	48.8	6.00	101
All ewes		251	9.9	12.0	44.4	5.31	101
Corriedale	6.0– 6.9	2	6.7	9.0	45.2	4.09	97
	7.0– 7.9	5	7.5	9.3	38.7	3.54	80
	8.0– 8.9	33	8.5	9.5	40.6	3.85	82
	9.0– 9.9	65	9.5	10.3	43.0	4.56	82
	10.0–10.9	66	10.4	10.9	43.7	4.76	83
	11.0–11.9	40	11.4	11.1	45.2	4.95	84
	12.0–12.9	23	12.2	11.4	45.7	5.17	82
	13.0–13.9	8	13.2	12.5	45.4	5.64	88
	14.0–14.9	1	14.0	10.3	51.4	5.27	91
	15.0–15.9	1	15.0	11.1	42.5	4.70	82
	16.0–16.9	1	16.0	14.6	42.3	6.17	91
All ewes		245	10.3	10.6	43.5	4.62	83

* Data on these characters should not be used for breed comparisons without correction according to method of Schott *et al.* (1942).

TABLE 2.—RELATIONSHIP BETWEEN STAPLE LENGTH, BODY WEIGHT AND FLEECE CHARACTERS

Breed	No. of ewes	Characters	Mean	Standard deviation, within years	Fleece length (x) with other characters (y)[3]			Body weight (x) with other characters (y)[3]		
					r[1]	Regression[1] $b_{y.x}$	Per cent reduction from standard deviation of mean to standard error of estimate	r[1]	Regression[1] $b_{y.x}$	Per cent reduction from standard deviation of mean to standard error of estimate
Rambouillet	206	Fleece length (cms.)	6.59	0.78	—	—	—	−0.16	−1.73	0
		Body weight (lbs.)	81.40	8.91	—	—	—	—	—	—
		Unscoured fleece wt. (lbs.)	9.79	1.50	0.38**	0.74**	7	0.52**	0.09**	15
		Clean yield (%)[2]	35.78	4.28	0.46**	2.52**	11	—	—	—
		Scoured fleece (lbs.)[2]	3.52	0.65	0.58**	0.50**	17	0.42**	0.03**	8
Targhee	281	Fleece length (cm.)	8.53	1.22	—	—	—	0.16**	0.20**	2
		Body weight (lbs.)	90.46	9.72	—	—	—	—	—	—
		Unscoured fleece wt. (lbs.)	11.12	1.70	0.43**	0.60**	9	0.41**	0.07**	8
		Clean yield (%)[2]	39.46	4.85	0.47**	1.90**	10	—	—	—
		Scoured fleece wt. (lbs.)[2]	4.39	0.86	0.61**	0.43**	21	0.34**	0.30**	6
Columbia	251	Fleece length (cms.)	9.90	1.39	—	—	—	0.12	0.02	1
		Body weight (lbs.)	101.30	10.26	—	—	—	—	—	—
		Unscoured fleece wt. (lbs.)	11.95	2.55	0.22**	0.40**	2	0.30**	0.08**	4
		Clean yield (%)[2]	44.41	4.60	0.15*	1.58*	12	—	—	—
		Scoured fleece wt. (lbs.)[2]	5.31	0.96	0.53**	0.37**	15	0.38**	0.04**	7
Corriedale	245	Fleece length (cms.)	10.30	1.36	—	—	—	0.12	0.02	0
		Body weight (lbs.)	82.85	9.45	—	—	—	—	—	—
		Unscoured fleece wt. (lbs.)	10.64	1.69	0.42**	0.53**	9	0.48**	0.09**	12
		Clean yield (%)[2]	43.52	4.72	0.24**	0.85**	1	—	—	—
		Scoured fleece wt. (lbs.)[2]	4.62	0.82	0.47**	0.28**	12	0.30**	0.03**	4

[1] Correlation and regression coefficients are averages within years determined by analysis of covariance.

[2] Bone dry determinations. Data on these characters should not be used for breed comparisons without correction according to method of Schott *et al.* (1942).

[3] Single asterisk indicates a significant coefficient ($P < 0.05$); double asterisk, a highly significant coefficient ($P < .01$).

It appears from data presented that $\frac{3}{8}$ to $\frac{1}{4}$ Blood fleeces produced on a large-bodied range sheep, when operated under Intermountain range conditions, such as prevail around Dubois, Idaho, show the greatest average unscoured and clean wool production.

Body weight had a significant relationship with unscoured and scoured fleece weights within years as indicated by the correlation and regression coefficients in table 2. The negative correlation found between body weight and fleece length in the Rambouillets was due entirely to data collected in one year. In this particular year the twin lambs were grazed apart from the single lambs and had longer staple but lighter body weights than the singles. It is believed that some environmental effects, not yet explained, brought about this inverse relationship. From observations made between the grazing areas of the twin and single lambs it is believed the longer staple length in the twins may be partially due to less brushing of the wool because the amount of sagebrush and browse is less prevalent on the range where the twin lambs were grazed.

There was a positive but low relationship between body weight and fleece length in the Targhee, Columbia and Corriedale breeds. The correlation was significant for the Targhee but not for the Columbia or Corriedale.

In general, body weight had a greater influence on unscoured fleece weight than on the other characters studied. From 4 to 15 per cent of the variation in unscoured fleece weight was associated with variation in body weight.

These results are in agreement with those of Spencer *et al.* (1928) who found a high correlation between body weight and unscoured fleece weight in Rambouillets. However, they reported a low correlation between body weight and clean weight. They also found a negative correlation between body weight and fleece length which may be explained by age variations as fleece length decreased steadily with age while fleece weights increased up to the third year. Furthermore, yearling ewes had the longest staple but the lightest fleeces. Duerden *et al.* (1932) presented results from Merino wool characters and concluded that there was no definite correlation between body weights and fleece weights, or between body weight and wool length. However, they concluded that if the sheep had been better bred and more uniform, a closer relationship between the weight of the sheep and the length of the woold might be expected. Terrill[5] found with yearling Rambouillet ewes that there were highly significant correlations between body weight and both scoured and unscoured fleece weight but that these were lower than the correlations between fleece length and scoured and unscoured

[5] Terrill, Clair E. Unpublished data.

[1] Single asterisk indicates a significant coefficient (P<.05); double asterisk indicates a highly significant coefficient (P<.01).

fleece weight. He also found a significant positive relationship between fleece length and body weight.

For practical wool improvement it is believed that more rapid progress may be made if greater emphasis is placed on fleece length, unscoured and/or scoured fleece weights. Results reported by Pohle (1942) show that staple length in weanling animals has a high relationship with that of the yearling, which means that sheep may be selected or culled at that age on fleece length with a reasonable degree of accuracy. While density is important in evaluating fleeces, where weight of fleece is the main objective it is believed that density will receive adequate consideration through its contribution to fleece weight. Body weight should be considered in any wool improvement program because it is associated with wool production, particularly with unscoured fleece weights. However, body weight is probably more important because of its relationship to lamb meat production. Other wool characteristics which are important include uniformity of length and fineness, strength, elasticity, contour or shape of fiber, and good felting and handling qualities.

Summary

Data on staple length, clean yield, unscoured and scoured fleece weight and body weight of 206 Rambouillet, 281 Targhee, 251 Columbia and 245 Corriedale yearling ewes, born during the years 1937 to 1940, inclusive, were used in this study. These sheep were raised under Intermountain range conditions at the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho. Commercial grade classification of wool from the four breeds studied represents Fine, ½ Blood, ⅜ Blood and ¼ Blood fleeces. Data are presented on the relation of staple length and body weight to wool production.

Data on all individuals are summarized, within staple length groups and a graphic picture is presented of the scoured and unscoured fleece weights of the entire population.

With each centimeter (⅜ inch) increase in staple length there was an average increase of from about ½ to ¾ pound of unscoured wool, ¼ to ½ pound of bone dry scoured wool per fleece and an increase of from .85 to 2.52 per cent in clean yield.

The increase in unscoured and scoured weight of fleece for each centimeter increase in length was greatest for Fine and ½ Blood wool. Length of staple had a greater influence on clean fleece weight than any other character studied. In general, body weight had a greater influence on unscoured fleece weight than on the other characters studied.

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THE MUSCLE-BONE RATIO AS AN INDEX OF MERIT IN BEEF AND DUAL-PURPOSE CATTLE

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Introduction

ONE of the greatest problems in measuring performance in beef cattle has been to devise a measure of merit from the standpoint of meat quality. Slaughter grade or carcass grade has been used from time to time, but it is subject to limitations of human judgment and does not seem to measure the exact qualities desired. From the standpoint of the consumer, as well as the packer, the most desirable carcass is one that contains just enough bone to give it form, enough fat for palatability and "ripening quality," and a large proportion of lean meat. Carcass grade is determined largely by the degree of fatness and in show steers there is often the objection that their carcasses contain so much fat there is considerable waste. It was thought that the ratio of lean meat or muscle to bone might offer an index of carcass merit that would be useful in selection, particularly in the progeny testing of bulls.

In this study the cut consisting of the 9th, 10th, and 11th ribs from the right side was used as a measure of the entire dressed carcass. Unpublished work by the Bureau of Animal Industry indicates that certain constituents of the 9–10–11-rib cut of the steer carcass are very closely related to the corresponding constituents of the dressed carcass. The coefficients of correlation and the corresponding estimating equations are given in table 1. Since these relationships are close enough to be of value in prediction of the composition of the entire dressed carcass, the writers have used in this study of the muscle-bone ratio the relationship as found in the 3-rib cut mentioned.

Material and Methods

The animals used in this study consisted of 135 Shorthorn steers which had completed record-of-performance feeding schedules at the Beltsville Research Center, Beltsville, Maryland. Of these 135 animals 55 were of the beef type and 80 of the dual-purpose type. All the steers were purebred animals and were used in evaluating sire performance on the basis of progeny tests. These animals were weaned at approximately 500 pounds of live weight at an average age of approximately 8 months, and were fed from 500 to 900 pounds on a ration of grain and alfalfa hay. The grain for some of the steers consisted of only shelled corn and for others a mixture of

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6 parts of corn, 2 parts of oats, 1 part of wheat bran, and 1 part of linseed meal. Number 2 leafy alfalfa hay was fed throughout. The animals were allowed all the concentrates they would consume, and were all individually fed. Concentrates were fed twice a day, morning and evening.

Upon reaching 900 pounds the steers were weighed and slaughtered. Carcasses were chilled and allowed to age for 10 days when samples were taken for analysis. The 9–10–11-rib cuts were separated into the lean

TABLE 1.—RELATION BETWEEN COMPOSITION OF THE 9–10–11-RIB CUT AND THE DRESSED CARCASS

Item studied	Correlation coefficients r	Regression	
		Regression equation	Standard error of estimate
Per cent separable fat in 9–10–11-rib cut with per cent separable fat of dressed carcass	+0.93	$Y=3.538+0.797$ (per cent separable fat in 9–10–11-rib cut)	2.14
Per cent separable lean in 9–10–11-rib cut with per cent separable lean of dressed carcass	+0.90	$Y=16.079+0.799$ (per cent separable lean in 9–10–11-rib cut)	1.94
Per cent bone in 9–10–11-rib cut with per cent bone of dressed carcass	+0.80	$Y=5.517+0.571$ (per cent bone in 9–10–11-rib cut)	1.26

meat, bone, and fat. These constituents were weighed, and the ratio of lean meat to bone determined. Correlation and analysis of variance studies were made as described by Snedecor (1937).

Data and Discussion

The distributions of the muscle-bone ratio for the two types of cattle involved in this study are shown in figure 1. The range in ratio for both types, considered as one group, was from 1.78 to 3.69. Two steers in the dual-purpose type were definitely higher in muscle-bone ratio than the general group of this type. An analysis of variance study indicated that there was a significant difference between types. The mean of the beef type was 2.55, and the mean of the dual-purpose type was 2.28. Approximately 15.6 per cent of the total variance was accounted for by difference between types. An analysis of the differences between the progeny of sires showed a highly significant difference within each type. These differences accounted for approximately 22 per cent of the total variance.

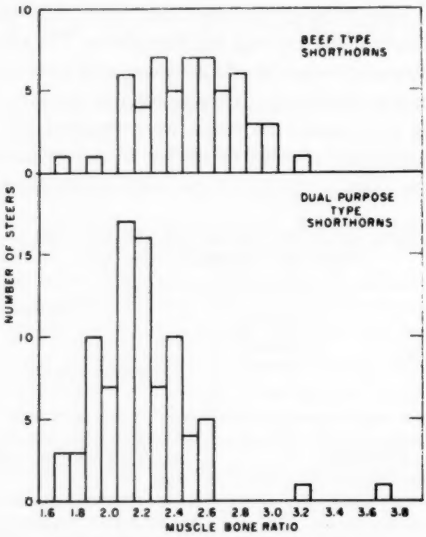

Figure 1. Distribution of muscle:bone ratio in beef and dual-purpose Shorthorn cattle.

The means of the progeny of sires in each type and the differences observed between sires are shown in tables 2 and 3. In the beef type significant differences were observed between the progeny of bulls 65 and 78, 65 and 123, 65 and 149, 95 and 149, and probable significant differences between 65

TABLE 2.—COMPARISON OF PROGENY OF BEEF SHORTHORN SIRES FOR MUSCLE:BONE RATIO

Herd number of sires	Number of calves	Average muscle:bone ratio	Differences between sires					
			Herd number of sires					
			78	95	110	123	149	180
65	11	2.30	.46**	.13	.25*	.39**	.45**	.27*
78	3	2.76		.33	.21	.07	.01	.19
95	8	2.43			.12	.26	.32**	.14
110	9	2.55				.14	.20	.02
123	5	2.69					.06	.12
149	11	2.75						.18
180	5	2.57						

* $P \leqq .05$. ** $P \leqq .01$.

and 110, 65 and 180. It should be noted that bulls 78, 95, and 180 are sons of bull 65, while 110 also is related to 65. Sires 123 and 149 are rather closely related. In the dual-purpose type the outstanding high ratio was observed in the progeny of C-45, and this bull was significantly higher than all of the other bulls in this type. There was a significant difference, however, between the progeny of A-74 and the progeny of two sons by this bull, C-2 and C-13.

TABLE 3.—COMPARISON OF PROGENY OF DUAL-PURPOSE SHORTHORN SIRES FOR MUSCLE:BONE RATIO

Herd number of sires	No. calves	Average muscle :bone ratio	Differences between sires									
			Herd number of sires									
			064	066	A74	A76	A99	Mo45	C2	C13	C45	C67
036	3	2.15	.08	.06	.03	.16	.11	.12	.23	.22	.77**	.26
064	3	2.07		.14	.05	.24	.19	.20	.31	.30	.85**	.34
066	12	2.21			.09	.10	.05	.06	.17	.16	.71**	.20
A74	15	2.12				.19	.14	.15	.26*	.25*	.80**	.29
A76	6	2.31					.05	.04	.07	.06	.61**	.10
A99	5	2.26						.01	.12	.11	.66**	.15
Mo45	8	2.27							.11	.10	.65**	.14
C2	6	2.38								.01	.54**	.03
C13	7	2.37									.55**	.04
C45	4	2.92										.51*
C67	3	2.41										

* P. ≦ .05. ** P ≦ .01.

The indications are that the muscle-bone ratio is a rather definitely inherited character. The fact that 22 per cent of variance in this factor is accounted for by differences between transmitting ability of bulls indicates that selections for a high muscle-bone ratio may result in a decided increase in this factor.

A correlation study was made within the beef Shorthorn type and within the dual-purpose Shorthorn type for the relationship between the muscle-bone ratio and various production factors, live animal measurements, and other carcass characteristics. The results are summarized in table 4.

The objection might be raised to the ratio under consideration that a high per cent of muscle and a low percentage of bone might result in a reduction in the percentage of separable fat in the carcass. For the two types of cattle the correlations were determined between muscle-bone ratio and percentage separable fat, and in neither instance was the value significant. This would indicate that the muscle-bone ratio can be increased without materially

affecting the ability of the animal to fatten. Therefore, if it is desired to increase or decrease the fatness, the feeding of steers over a longer or shorter period of time would control this factor.

Correlations between the muscle-bone ratio and live animal measurements gave little indication that selections could be made on conformation of the live animal for this particular characteristic. Circumference of cannon bone showed a fair negative correlation in the beef Shorthorn, but was not

TABLE 4.—CORRELATIONS BETWEEN MUSCLE:BONE RATIO AND OTHER FACTORS

Correlations: Muscle:bone ratio with—	Within beef Shorthorn type	Within dual-purpose type
Carcass characteristics and measurements		
Per cent of separable fat	.19	.11
Leg bones as per cent of final weight	−.25	−.32**
Length of hind leg	−.07	−.28**
Thickness of muscle and fat over rib[1]	.29	.30**
Thickness of fat over rib[1]	.17	.14
Length of body/empty body weight	−.27	−.19
Live animal measurements		
Height at withers	.13	−.05
Heart girth	.13	−.12
Circumference of cannon bone	−.26	−.04
Width of chest	−.06	−.16
Production factors		
Efficiency of gain	−.04	
Age of steer at slaughter	−.08	

[1] Average of measurements at three points.

** Denotes statistically significant correlation $P \leqq .01$.

large enough to be significant, and the correlation in the dual-purpose Shorthorn was approximately 0. It should be expected that the smaller the bone, the higher the muscle-bone ratio. The correlations are not high enough to be of value. Indications are from a study of the measurements that little can be gained in muscle-bone ratio by the selection for type and quality as they are usually evaluated. Some studies have shown that certain body measurements are associated with slaughter and carcass grade. For example, such measures as height at withers, heart girth, and width of body have been shown to be correlated with grade (Black, Knapp, and Cook, 1938). The correlation between height at withers and grade was negative and the others positive. These relationships were apparently determined to a large extent by the fatness of the animals.

Correlations with carcass measurements were in general higher than those with the live animal measurements. The highest and only significant cor-

relations observed were in the dual-purpose Shorthorn type between the muscle: bone ratio and leg-bones as a per cent of live weight, length of hind leg, and thickness of muscle and fat over the rib. Although these correlations in the dual-purpose Shorthorn type were statistically significant, they were of rather low predictive value and of little importance as a means of measuring muscle-bone ratio. No correlation was found between the latter and efficiency of gain. This would indicate that in selecting for efficiency of gain

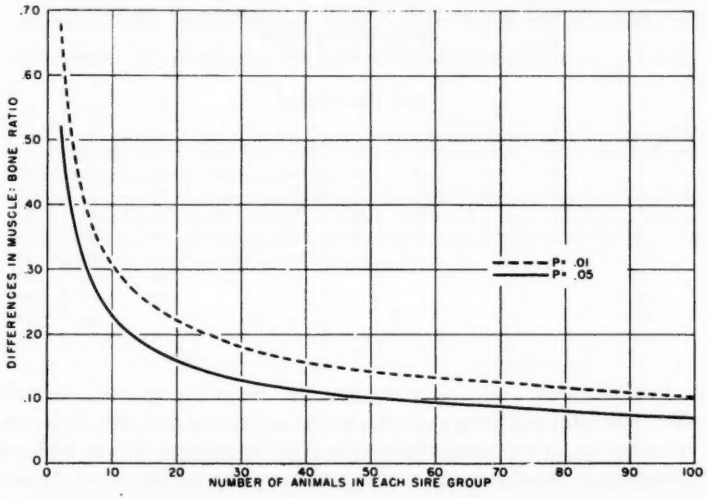

Figure 2. Number of animals necessary to test a sire. The curves show the differences in muscle: bone ratio between sire-progeny groups that are necessary to be significant at the levels of P = .05 and P = .01.

there would not be a tendency to select against a high muscle-bone ratio. Steers used in this study varied in age from 355 to 604 days at 900 pounds live weight, but there was no correlation between the age of the steer at slaughter and the ratio.

If this ratio is to be used in performance studies, some indication of the number of animals required and the necessary differences between the progeny of various sires is necessary. Using the method described by Hetzer and Brier (1939), the indications are that beyond about 10 animals, relatively little information is added per steer studied. This is shown in figure 2. Greater numbers would give more accuracy, of course, but it should be emphasized again that the information obtained decreases with each additional animal. For example, a necessary difference of half the value of 10

animals would require 40 animals from each sire. Examination of figure 2 shows that differences of 0.2 to 0.3 in the ratio are significant with 10 animals per sire and inspection of tables 2 and 3 shows that differences of this magnitude occur rather frequently. The necessary differences for *P* values of 0.05 for varying numbers of progeny are shown in table 5. These and similar values were used in determining the significance between the bulls as shown in tables 2 and 3.

TABLE 5.—NECESSARY DIFFERENCES IN MUSCLE-BONE RATIO TO BE SIGNIFICANT (P=.05) FOR VARYING NUMBERS OF PROGENY IN EACH SIRE GROUP

N_2 \ N_1	2	4	6	8	10	12	16	20	30
2	.52	.45	.42	.41	.40	.39	.39	.38	.38
4		.37	.33	.32	.31	.30	.29	.28	.27
6			.30	.28	.27	.26	.25	.24	.23
8				.26	.24	.24	.22	.22	.21
10					.23	.22	.21	.20	.19
12						.21	.20	.19	.18
16							.18	.17	.16
20								.16	.15
30									.13

It would seem from this study that the use of the muscle-bone ratio offers possibilities of being a valuable tool in selection of beef sires. This ratio is now in use, as one index of selection, in the breeding studies on beef and dual-purpose Shorthorn cattle, being conducted by the Bureau of Animal Industry. Such use will determine more fully its value for the purpose indicated.

Summary

A study was made of the muscle-bone ratio in 135 steers, 55 of which were beef Shorthorn and 80 dual-purpose Shorthorn. Statistically significant differences were observed between the types which accounted for approximately 15.6 per cent of the total variance. There was a significant difference between sires within each type which accounted for approximately 22 per cent of the total variance. Tests for differences between sire groups within each type showed several highly significant differences.

No significant correlation was found within types between muscle-bone ratio and per cent of separable fat in the carcass.

No relationship was found between live animal measurements and the muscle-bone ratio, indicating that selections could not be made on the basis of conformation as evaluated by such measurements.

There were significant correlations between some of the carcass measurements and the muscle-bone ratio, but none were high enough to be of value in predicting muscle-bone ratio within types. The highest relationships were with leg bones as a percentage of live weight and the average thickness of the meat over the rib.

There was no relationship between muscle-bone ratio and efficiency of gain or age of steer at slaughter.

Necessary differences were calculated between sire groups, and it was determined that beyond approximately 10 steer offspring, relatively little information was obtained for each additional steer studied.

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COMPARATIVE LENGTHS OF THE GESTATION PERIODS OF ABERDEEN-ANGUS AND HEREFORD COWS CARRYING PUREBRED AND CROSSBRED CALVES

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THE average gestation period of cattle is stated by Lush (1937) to be 282.1 days. This figure is based on 27,810 gestations, and is based on published accounts dealing with various breeds and from various places. Critical data as to whether or not significant differences exist between the average gestation periods of the various beef breeds are not available in published form. The beef cattle project now under way at the Ohio Experiment Station provides an excellent opportunity to obtain such data for the Aberdeen-Angus and Hereford breeds. The project has been under way since 1939, and has for its primary objective the determination of the relative rate and efficiency of gains in the feed-lot of Aberdeen-Angus and Hereford cattle and of crosses between the two breeds.

To date twenty-eight purebred Aberdeen-Angus and twenty-nine purebred Hereford cows have been used for breeding purposes. According to the plan, each cow is bred to an Aberdeen-Angus and a Hereford bull in alternate years. Thus over a two-year period each cow should produce a purebred and a crossbred calf. As nearly as possible, equal numbers of purebred Aberdeen-Angus, purebred Herefords, crossbred calves from Aberdeen-Angus sires and crossbred calves from Hereford sires are produced each season.

Two crops of calves have been produced. Data on the gestation periods of their dams are shown in table 1. During this two-year period, the 57 cows produced 100 calves. Forty of the cows produced both a purebred and a crossbred calf. One Aberdeen-Angus (No. 26) produced two purebred calves, while another (No. 19), produced two crossbred calves. One Hereford cow (No. 84) produced two crossbred calves. The other fourteen cows produced one calf each.

Hereford dams with Hereford calves *in utero* had an average gestation period of 289 days, whereas the Aberdeen-Angus averaged only 272.8 days, a difference of 16.2 days. Dams with crossbred calves, regardless of which way the crosses were made, averaged 281.4 days during gestation, very nearly intermediate between the two pure breeds. Not only are these differences highly significant (see table 2), but they are quite consistent for individual cows. Only three of the Aberdeen-Angus cows (No. 30, 18 and

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TABLE 1.—THE NUMBER OF DAYS IN GESTATION FOR INDIVIDUAL COWS

Hereford cows			Aberdeen Angus cows		
Cow No.	Purebred calves	Crossbred calves	Cow No.	Purebred calves	Crossbred calves
48	288	304	1	279	285
49	288	—	2	273	284
55	—	282	5	279	284
58	286	—	6	271	280
59	—	282	7	245	285
61	294	284	8	275	282
68	289	286	9	277	282
69	290	—	10	261	265
70	285	280	11	278	285
71	316	278	12	279	281
72	—	278	13	283	280
74	287	279	14	273	277
75	284	287	15	265	274
77	290	287	16	253	280
78	285	276	18	283	277
79	289	285	19	—	277
80	287	283		—	288
81	286	278	20	275	283
82	289	279	21	277	279
84	—	282	22	244	283
	—	276	23	—	289
89	287	280	24	277	285
91	290	286	25	275	285
93	285	279	26	275	—
97	—	252		285	—
98	282	280	27	279	288
40	—	282	28	275	280
53	—	290	29	276	—
73	—	277	30	278	275
90	—	285	32	277	—
Total No. Calves	20	27		27	26
Mean No. Days	289.0±1.56	281.4±1.56		272.8±1.89	281.4±0.95

TABLE 2.—DIFFERENCES IN LENGTHS OF GESTATION PERIODS OF HEREFORD AND ABERDEEN-ANGUS DAMS WHILE CARRYING PUREBRED AND CROSSBRED CALVES

Groups compared	Difference, in days
Purebred Hereford vs purebred Aberdeen-Angus	16.2±2.45
Purebred Hereford vs crossbred (Aberdeen-Angus sire)	7.6±2.20
Purebred Hereford vs crossbred (Aberdeen-Angus dam)	7.6±1.82
Purebred Aberdeen-Angus vs crossbred (Hereford sire)	8.6±2.11
Purebred Aberdeen-Angus vs crossbred (Hereford dam)	8.6±2.45
Crossbred (Hereford sire) vs crossbred (Aberdeen-Angus sire)	0.0±1.82

13), had longer gestation periods for purebred than for crossbred calves, whereas only two of the Hereford cows (No. 48 and 75) had shorter gestation periods for purebred than for crossbred calves. The fact that the dams carrying crossbreds show gestation periods intermediate between the purebreds, regardless of which way the cross is made, strongly indicates that the length of the gestation period depends upon the genotype of the fetus, rather than upon that of the dam.

Summary

Hereford dams with Hereford calves *in utero* showed an average gestation period of 289 days. Aberdeen-Angus dams with Aberdeen-Angus calves showed an average gestation period of 272.8 days. Dams with crossbred calves, regardless of which way the cross was made, showed an average gestation period of 281.4 days.

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THE RELATION OF ASCORBIC ACID TO BREEDING PERFORMANCE IN HORSES[1]

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IN THE course of investigations as to the chemical and physical properties of spermatazoa of the stallion, the erratic production of good motile samples led to attempts at improving the quality of the sperm. Reports from the Wisconsin workers (Phillips *et al.*, 1940) with cattle suggested the injection of vitamin C. The favorable results obtained led us to make a survey of the blood ascorbic acid of the stallions, geldings and mares of the college herd and of saddle mares at the Northwind Farms, located a short distance from the campus.

The results of the ascorbic acid determinations made on the horses and some of the relationships to reproductive performance are reported here.

Material and Methods

The values obtained have been divided into several classes according to the observations made on the different animals.

The first experiment was performed on a Belgian stallion three years old in the spring of 1940. This animal was injected with ascorbic acid and given ascorbic acid orally in successful attempts to improve the quality of the semen. Semen was drawn using an artificial vagina and dummy mare which the stallion had been trained to mount, and was analyzed for ascorbic acid by Bessey's (1938) modification of Mindlin and Butler's (1937) method.

As a result of the first experiment with the stallion, blood ascorbic acid determinations were made on mares and their breeding history followed to determine if differences were apparent. In addition, determinations were made on the blood of stallions, geldings and young horses. Blood was drawn from the jugular vein of the horse and rapidly mixed with lithium citrate as an anti-coagulant. The samples were then transported rapidly to the laboratory and ascorbic acid determinations made immediately. Use was made of a thermos jug to maintain a cold temperature, although it was rare that more than 45 minutes elapsed between the time blood was drawn and determinations begun. Ascorbic acid was determined in the blood using the method of Mindlin and Butler (1937).

Because use of ascorbic acid had improved the reproductive function of a

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stallion, two mares with a history of failure to come into heat were given ascorbic acid orally.

Data and Discussion

Ascorbic Acid Therapy on a Stallion

A three-year-old Belgian stallion was being used as a source of semen for preservation studies and during the fall of 1939 the samples became uniformly poor to the point where practically no sperm were present and motility was lacking. At this time, because of reports from the Wisconsin workers, it was decided to inject ascorbic acid.

At the time of the first injection in January 1940 the ascorbic acid content of the semen was less than 0.0001 mg. per cc. The sperm in this semen showed no motility. Four injections of 1 gram of ascorbic acid given at 3-day intervals resulted in an increase in motility of the sperm to the point of approximately 70% activity. The sperm count rose to between 2 and 4 billion. The ascorbic acid was discontinued and within two weeks' time the motility had descreased to less than 10%. In March of 1940 the injections were repeated for a period of four weeks with equally good results. However, when the vitamin C was discontinued the quality of the semen rapidly deteriorated.

Because of an infection appearing at the point of injection it was decided to feed the ascorbic acid by capsule, in subsequent experiments, at the rate of one gram daily.

Between June 1940 and April 1941 three complete cycles of ascorbic acid feeding were carried through. In each, the administration of the ascorbic acid improved semen quality while with the cessation of ascorbic acid feeding the semen quality deteriorated.

The blood ascorbic acid responded to the administration of ascorbic acid, reaching a high level of 0.35 mg. per cent. The lowest value recorded was 0.08 mg. per cent. The ascorbic acid of the semen varied with the administration of the ascorbic acid but more particularly with the quantity of the ejaculate. A high value of 0.004 mg. per cc. was obtained in a sample of 35 cc. containing highly motile sperm. A subsequent sample of 125 cc. of equally motile sperm contained only 0.002 mg. per cc.

While only one animal was used in this work the repeated response to ascorbic acid administration has led us to the conclusion that it played an important role in the production of motile sperm in this stallion.

Ascorbic Acid Therapy on Mares

Two mares of a heavy breed which had failed to come in heat in 1940 had been treated with anterior pituitary extract. Both came in heat and

TABLE 1.—COMPARISON OF LEVELS OF ASCORBIC ACID IN BLOOD PLASMA OF MARES CLASSIFIED AS GOOD AND DIFFICULT BREEDERS. DATA WERE OBTAINED IN MONTH PREVIOUS TO FIRST BREEDING ATTEMPT

Items	Mares of heavy breeds		Mares of light breed	
	Good breeders	Difficult breeders	Good breeders	Difficult breeders
	mg. per 100 ml.	mg. per 100 ml.	mg. per 100 ml.	mg. per 100 ml.
Highest value	0.22	0.10	0.15	0.11
Lowest value	.11	.04	.11	.06
Average	.15	.07	.13	.09
Degrees of freedom	25		15	
Differences between good and difficult breeders	0.08		0.04	
F value	48.7		22.7	
F value required for 1% level of significance	7.82		8.86	

were bred. Both settled, but one (a 21-year-old mare) aborted in the seventh month of pregnancy. In 1941 both mares again failed to come in heat. A check of ascorbic acid values showed that they fell in the lower range, being 0.09 and 0.11 mg. per cent. Ascorbic acid feeding by capsule at the rate of one gram per day was instituted. After 30 days the first mare came in heat and was bred. Her blood ascorbic acid value was 0.15 mg. per cent. This mare did not settle. The second mare came in heat 40 days after ascorbic acid feeding was started and was bred and settled. Her blood ascorbic acid had risen to 0.20 mg. per cent at the time of breeding.

Ascorbic Acid in Blood

The ascorbic acid values obtained in the blood of mares during the month of the spring in which breeding was first attempted for the years 1940 and 1941 are presented in table 1. Statistical treatment is included in the tables. The division of good and difficult breeders was made arbitrarily. Mares which had to be bred in more than two consecutive heat periods were considered difficult or poor breeders. It should be noted though that many of these mares subsequently were settled in foal. Determinations were made on 24 additional females, but these values are not included in the tables for lack of breeding history, the animals either were sold or not bred because of immaturity.

TABLE 2.—ASCORBIC ACID CONTENT OF THE BLOOD OF STALLIONS AND GELDINGS

Animals studied	No. of animals	Mg. ascorbic acid per 100 ml. plasma
Belgian stallions	6	0.139
Percheron stallions	4	0.120
Stallions of light breeds	2	0.102
Total	12	0.126
Geldings	19	0.070

When the average values for the mares of heavy breeds are considered it will be noted that the values for the good breeders are twice those of the poor breeders. In the case of the mares of light breeds the difference is not so pronounced. Statistical treatment by the method of analysis of variance indicates that the differences between good and difficult breeders is significant at the 1% level, both with heavy and light breeds.

In the spring of 1942 it was decided to follow the ascorbic acid values of mares in the college herd through the breeding period. However, although 23 mares were observed, the criterion set up arbitrarily for a difficult breeder eliminated all but two mares inasmuch as 13 mares settled on first service and 8 on the second service. The two not settled had both suffered an abortion the previous year, and possibly this accounted for their failure to settle. The average value for ascorbic acid in the 21 mares was 0.157 mg. per 100 ml. of plasma, a value corresponding closely to the average for good breeders in previous years. It should be noted here, however, that three mares which settled on first or second service were quite low in blood ascorbic acid with values of 0.06, 0.08, and 0.09 mg. per cent. The range for the other 18 mares was from 0.12 to 0.30 mg. per cent.

It will be noted that there occur quite large differences in blood ascorbic acid values (table 1) among animals classed as good breeders and it has been noted that there are animals which consistently have higher values, although the trend is for good breeders to have higher values and others lower values.

On the supposition that feed may play some part in the ascorbic acid found in the blood, average values are presented for blood ascorbic acid in the seasons: spring, before pasture; spring, pasture to July 1; summer pasture; fall pasture to Nov. 15; winter to Feb. 1 (table 3). The values are merely suggestive inasmuch as values are averages of different numbers of mares, only six mares having had determinations made in the fall season.

The lowest value of 0.09 mg. per cent was that for the early spring before

TABLE 3.—ASCORBIC ACID CONTENT OF THE BLOOD OF MARES OF HEAVY BREEDS AT DIFFERENT SEASONS

Season	No. of determinations[1]	Average mg. ascorbic acid per 100 ml. plasma
Spring, before pasture	23	0.09
Spring pasture to July 1	56	.17
Summer, to Sept. 15	14	.11
Fall, to Nov. 15	6	.14
Winter, to Feb. 1	23	.11

[1] Data obtained during 1940, 1941 and 1942.

the animals were placed on pasture. This was followed by the highest value of 0.17 mg. per cent in late spring when the pasture is usually at its best. Summer with its older pasture and winter had comparable average values of 0.11 mg. per cent, while the fall pasture season average was 0.14 mg. per cent. These are average values and it should be noted that in all seasons there was a range of values from less than 0.10 mg. to more than 0.17 mg. per cent. This is important to consider inasmuch as the values used in table 1 come almost entirely from the mares bred in the last two weeks before pasture and during the spring pasture period. The data in table 1 were taken during the months of May and June.

In table 2 is presented the average values obtained on the blood of stallions and geldings. It will be noted that the stallions had considerably higher values for ascorbic acid than the geldings. The explanation for this is not clear. An analysis of the feed of both classes of horses failed to reveal appreciable quantities of ascorbic acid in either of the biologically active forms. All the stallions were settling mares when blood ascorbic acid values were determined.

Discussion

The ascorbic acid values presented here indicate strongly that there is a relationship between the breeding efficiency of stallions and mares and the ascorbic acid content as found in the blood. The response of the stallion was strongly indicative of this and the repeated performance gives the results added weight.

The values obtained on mares in 1940 and 1941, table 1, showed that there was apparently a significant difference between the good breeders and difficult breeders. In 1942, however, the presence of good breeders with low values raised a question as to individual differences and makes it difficult to indicate a range of blood ascorbic acid which may be considered adequate for good breeding performance. A possible explanation of the success of the

breeding program may be in the fact that pasture was unusually early in East Lansing with the result that nearly all of the mares were on pasture before being bred. As shown in table 3, we have observed that blood ascorbic acid values rise with the advent of pasture. The opposite picture is also shown in the case of the geldings which received little if any ascorbic acid in their feed and had consistently low blood ascorbic acid values.

The data on ascorbic acid therapy are inadequate due to the lack of more animals with poor breeding histories that could be treated. Consequently, while the data on the two mares which were brought into heat look encouraging, additional data must be accumulated before any conclusions can be drawn.

In the course of three years approximately 100 different horses have been tested for blood ascorbic acid. The fact, however, that these consist of draft horses and saddle horses, mares, geldings, and stallions, old and young, makes it difficult to draw definite conclusions and points out the necessity for additional work.

Summary

1. Blood ascorbic acid values for good breeders, in mares of both heavy and light breeds, were significantly higher than those of poor breeders.

2. Good breeding Belgian and Percheron mares had an average value of 0.15 mg. per cent of plasma as against 0.07 mg. per cent for difficult breeders.

3. Corresponding values for light horse breeds were 0.129 and 0.09 mg. per cent of blood plasma.

4. Individuals differ widely in blood ascorbic acid value.

5. Results with one stallion indicate a possible role of ascorbic acid in the production of motile sperm.

6. Mares going on pasture show a rise in blood ascorbic acid values.

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SEASONAL CHANGES IN THE LIGNIN AND CELLULOSE CONTENT OF SOME MONTANA GRASSES. II[1]

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FOR reasons set forth by Crampton and Maynard (1938), Norman (1939), Maynard (1940), and others, it is generally accepted that information concerning the lignin and cellulose contents of forage plants at different stages of maturity is of interest to the animal nutritionist. Seasonal increases in lignin and cellulose during 1940 were previously reported by Patton and Gieseker (1942). The present paper gives data for grasses from the same plantings during the 1941 season, and four additional species as well.

Material and Methods

The growth stages suggested by McCarty (1938), and used in the 1940 season, are believed to be more desirable from the plant physiologist's standpoint than from the standpoint of the animal nutritionist. For this reason, a system was adopted in 1941, based largely on the recommendations of the Forest Service, the U. S. D. A., and ranchers in this area:

1941 Growth Stages:

1. Remnants of previous year's growth (early spring).
2. First growth of leaves in spring.
3. Plants in full bloom.
4. Seeds ripe.
5. Seeds fallen, plant dried (early fall).

For purposes of comparison, these stages may be readily compared with stages used in 1940.

A sample consisted of several plants of the same species and growth stage, collected at random, and containing at least one pound of dry grass. Since grass was sampled at certain stages rather than at definite dates, it was necessary to observe the grass every few days in order to be on hand when the time for sampling arrived. Many grasses pass from stages 4 to 5 very quickly, and there is the possibility of missing a stage entirely.

Samples were cut at the minimum height possible without getting soil in the sample. This was usually about one inch above the crown. Samples were immediately dehydrated and enzymes destroyed in a forced-air oven at approximately 65 degrees Centigrade (Link, 1925). Grass was chosen to be as free from dust as possible, but samples were not washed for fear of losing

[1] Contribution from the Chemistry Research Department, Montana Agricultural Experiment Station, Bozeman, Montana. Approved by the Director for Publication as Paper No. 177, Journal Series.

soluble constituents. Since grass varies in chemical composition from morning to night, samples were usually collected between 9 and 12 a. m.

After the preliminary drying the samples were ground in a Wiley mill to pass through a 0.5 mm. screen, and stored in stoppered bottles. Official methods were used for determining crude protein, ether extract, total ash, and residual moisture for calculating to the dry basis. Lignin and cellulose were determined by the method of Crampton and Maynard (1938), modified as follows:

Lignin Procedure. Weigh out duplicate one gram samples of grass previously dried at 65° C. and ground to 0.5 mm. and extract with ether for 16 hours by means of a Bailey-Walker extractor. Transfer the dried residue into 50 ml. glass-stoppered Erlenmeyer flasks and add 40 ml. of a 2.0 per cent solution of pepsin in 0.1 N HCl. Digest overnight at 40° C. Recover the undigested residue by filtration through 200-mesh bolting silk in a Gooch crucible. Wash successively with hot water, hot alcohol, hot benzene, hot alcohol and ether. Transfer the washed residue to a 100-ml. beaker, and allow the ether to evaporate. Moisten the residue with 4 ml. of 35 per cent formaldehyde. Partly immerse the beaker in a cold water bath to prevent the temperature from rising above 70° C. Then add 4 ml. of 72 per cent H_2SO_4, allowing it to penetrate the sample (2 minutes). Add 6 ml. of concentrated H_2SO_4, and stir vigorously with a glass rod to aid in solution, which should be complete in from 10 to 15 minutes. When sample is dissolved, stir in 35 cc. of a granulating reagent consisting of a 1:6 mixture (by volume) of chloroform and glacial acetic acid, and pour the whole into 500 ml. distilled water in an 800 ml. beaker. Boil gently under a hood until the chloroform has been driven off (15 minutes), after which the solution should clear and the lignin settle in granular form. Filter (using asbestos) in a Gooch crucible with suction. Wash in not less than 200 ml. of 5 per cent HCl. Dry at 110° and determine lignin by loss on ignition.

Cellulose Procedure. Weigh out duplicate one gram samples of grass previously dried at 65° C. and ground to 0.5 mm., and place in 6-inch Pyrex centrifuge tubes. Add 15 ml. of 80 per cent acetic acid and 1.5 ml. conc. HNO_3. Place water-filled Battersea crucibles, top diameter 30 mm., into the necks of the centrifuge tubes. This serves as a simplified reflux condenser. Boil gently for 20 minutes on a sand bath. Cool centrifuge tubes with cold water and remove Battersea crucibles. Add about 20 ml. of alcohol, mixing well with stirring rod. Centrifuge until precipitate settles. Decant the liquid. Wash (in centrifuge tube) successively with alcohol (2 washings), hot benzene, hot alcohol, ether. If residue is still acid, washing has not been thorough. Dry residue in centrifuge tube at room temperature until no noticeable ether odor remains, and place in oven at 100° C. for one hour. Cool in a desic-

TABLE 1.—PER CENT LIGNIN AND CELLULOSE AT VARIOUS STAGES OF MATURITY (1941)

Type of grass	Stage	Lignin	Cellulose
		per cent	*per cent*
Standard Crested Wheatgrass	1	18.9	48.3
Agropyron cristatum (L.) Gaertn.	2	5.5	22.5
	3	13.6	29.7
	4	14.4	32.3
	5	17.9	42.0
Fairway Crested Wheatgrass	1	17.1	41.1
Agropyron cristatum (L.) Gaertn.	2	6.0	21.3
	3	11.6	27.4
	4	14.4	32.8
	5	20.4	40.8
Slender Wheatgrass	1	14.2	41.8
Agropyron pauciflorum (Schwein) Hitch.	2	4.8	21.6
	3	10.6	32.5
	4	13.9	34.9
	5	16.2	41.0
Smooth Brome Grass	1	17.4	44.7
Bromus inermis Leyss.	2	4.2	20.1
	3	14.6	31.8
	4	14.1	33.1
	5	17.9	45.5
Mountain Brome Grass	1	12.0	43.0
Bromus marginatus Nees.	2	4.5	19.9
	3	11.3	26.9
	4	14.4	33.7
	5	16.6	45.2
Tall Oatgrass	2	4.1	20.6
Arrhenatherum elatius (L.)	3	12.0	30.9
Mert. and Koch	4	11.7	29.8
	5	16.5	43.5
Blue Grama	2	12.6	24.8
Bouteloua gracilis (H.B.K.) Lag.	3	12.7	29.0
	4	15.2	29.2
	5	14.9	35.2
Russian Wild-Rye	1	11.9	35.8
Elymus junceus Fisch.	2	4.4	18.8
	3	8.8	24.6
	4	10.8	29.2
	5	11.4	28.7
Tall fescue	2	4.0	18.5
Festuca elatior L. (var. arundinacea)	3	10.4	28.9
	4	15.5	37.6
	5	20.3	46.8

cator, and weigh. Add a few ml. of alcohol, ignite in a muffle furnace while still in the centrifuge tube, cool and weigh again. Loss in weight on ignition is recorded as per cent cellulose.

Data and Discussion

The data resulting from the analyses of samples are presented in table 1.

In general, the increase in lignin and cellulose during growth appears to have been similar in the various species during both seasons, with a coefficient of correlation between lignin and cellulose greater than 0.9 for 123 samples analyzed. An exception appears to be blue grama grass, which had an amazingly high lignin content in the early vegetative stage. Samples collected in another section of Montana corroborated this high lignin content.

Due to peculiar growth habits and the abundance of new basal leaves throughout the season, some difficulty was experienced in obtaining accurate samples of Russian wild rye at definite stages of growth. The values reported for this grass are composites from a larger number of samples, and are believed to be representative.

Summary

A study was made of the lignin and cellulose contents of nine Montana grasses collected throughout the 1941 growing season. Methods of collection and analysis are discussed, and a table of analytical results is given.

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EVALUATION OF FEEDS ON THE BASIS OF NET AVAILABLE NUTRIENTS[1]

Report of the American Society of Animal Production's Special Committee on Evaluation of Feeds[2]

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THE objectives in the preparation of this report have been (1) to review the development of the ideas and procedures involved in the evaluation of feeds on the basis of net available nutrients, (2) to point out the basic factors affecting food utilization, (3) to compare the significance of the various methods that have been employed, and (4) to consider the most practicable use that can be made of the net-energy conception in the evaluation of feeds.

The Fundamental Conception

The fundamental principle underlying all methods of evaluation of feeds on the basis of net available nutrients is the net-energy conception, in accord with which all organic nutrients are measured in terms of calories, and the net available portion of any nutritive substance is that portion of its gross energy which remains after the deduction of all energy losses and expenses incident to the processes of utilization. It is represented by the simple formula: Net energy = gross energy minus energy of urine, feces, methane and heat increment. Although this principle was formulated at a time when very little was known about the role of amino acids, minerals, vitamins and other essential factors in nutrition, and although the later findings profoundly affect the practical aspect of the application of the net energy idea, its fundamental validity remains unchanged and unquestionable.

Ideas of Various Workers

Kellner's ideas. Kellner (1905) first applied this principle to the evaluation of feeds for fattening. Kellner's original idea was that the production or net-energy value of a feed depends entirely on the kinds and quantities of digestible organic nutrients it contains regardless of the combination in which it is fed. He therefore proceeded to determine, in respiration and balance experiments, the proportions of the energy of pure carbohydrate, protein and

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[2] The members of this committee are: E. B. Forbes, State College, Pa., Chairman; H. H. Mitchell, Urbana, Ill.; G. S. Fraps, College Station, Texas; F. B. Morrison, Ithaca, N. Y.; C. C. Culbertson, Ames, Iowa; E. W. Crampton, Quebec, Canada; M. Kleiber, Davis, Calif.; A. G. Hogan, Columbia, Mo.; L. A. Maynard, Ithaca, N. Y.; Max Kriss, State College, Pa.

[3] Max Kriss died on Nov. 16, 1941.

fat that are recovered in the body gains of flesh and fat, using for this purpose starch, sugar, straw pulp, wheat gluten and oil as supplements to a basal maintenance ration. On the basis of these determinations, and using the value for starch as a unit of reference, he calculated from the digestible nutrients of many feeding stuffs their net energy values for body increase in terms of starch equivalents. He also determined the production values of a number of feeding stuffs directly.

The outstanding fact of importance in relation to the present problem is the later discovery of Kellner that his computed starch values did not agree very well with his direct determinations, especially in the case of roughages. Kellner explained these differences as being due to the extra energy expended in the utilization of crude fiber, and worked out empirical corrections for general use on the basis of comparisons between the computed and the experimentally determined starch values. The derivation of the correction (Wertigkeit) factors for relative values constitutes one of the weak points in the Kellner system. Corrections for only a few feeding stuffs have actually been determined, and in some cases they are of considerable magnitude. The computation is based on the questionable assumption that the differences between the experimentally determined and the computed starch values are entirely due to the crude fiber content of the test substance, and the individual determinations of the starch equivalents for the different nutrients show considerable variability.

Kellner's production values for starch, protein and fat calculated in terms of the percentages of their metabolizable energy (Axelsson, 1939) are as follows: The values for starch vary from 54.2% to 65.2%, the average of seven determinations being 58.9%. The values for fat, of which only three were determined, are 52.2%, 59.4% and 70.6%. Kellner omitted the last result from his average. The values for protein are 45%, 42.7% and 32.9%. The last value was omitted by Kellner and the remaining two were averaged with two figures from Kuhn's results (45.1% and 47.4%). The average values determined for the net availability of the metabolizable energy of starch, fat and protein were 58.9%, 56.3% and 45.2%, respectively.

Inasmuch as the production values of feeding stuffs are calculated, according to the Kellner system, in terms of starch equivalents, especial importance attaches to the determinations of the productive energy of starch. Attention has already been called to the variability of the coefficients of utilization of metabolizable energy of starch as calculated by Axelsson from Kellner's data. Further evidence of the variability of the energy value of starch is derived from the fact that the experimental results of Armsby and Fries (1918) on the net availability of metabolizable energy of starch are also quite variable and are considerably lower (ave. 48%) than those calculated by them

from Kellner's data (ave. 58.8%). No explanation was given by Armsby for this difference, but he called attention to the difference in the quantity and the make-up of the rations used in his and in Kellner's experiments.

Møllgaard's ideas. Møllgaard (1929) has concluded, on the basis of his own observations, that the ratio of the protein energy to the total energy of a ration (quotient of production) is an important factor as affecting the utilization of the metabolizable energy, especially for milk production. Møllgaard (1939) holds that there is at present no better method for the determination of net energy than the classical differential procedure. However, he considers it impossible to determine net energy values of individual feeding stuffs for milk production by this difference method. He has expressed energy requirements for milk production, and relative energy values of feeds for milk production (milk production equivalents), in terms of net energy for fattening (NKF) on the basis of the determined relationship between calories of milk energy and equivalent calories of net energy (for fattening) of mixed rations.

Armsby's ideas. Armsby first approached the problem of determination of the net energy values of feeding stuffs from the point of view that the metabolizable energy and the heat increment values are the two basic factors characterizing the usefulness of a feed, and with an open mind as to the possible effects of the plane of nutrition, and the purpose for which food is used, on these factors. Indeed, the question of whether the net availability of the metabolizable energy of a feed for maintenance is the same as or different from that for body increase is one of the problems to which Armsby devoted much attention from the beginning of his respiration calorimetric studies.

While Kellner directed most of his studies toward the determination of production values above the point of maintenance, Armsby used in his experiments both submaintenance and supermaintenance rations. Guided by the experimental results, and because of their conflicting character, Armsby changed his views, from time to time, on the question of the influence of the plane of nutrition, and his conclusions on this point affected not only the plan and the objectives of his subsequent experiments, but also his method of calculation of the maintenance requirements of animals, and his formulation of standards in terms of net energy. The following excerpts from Armsby's writings reveal the changes in the position taken by him at various times on this important question of maintenance vs. production values; and they are also significant as indicating some of the difficulties associated with determinations of net-energy values of feeding stuffs.

In 1903 Armsby wrote:

> Our results indicate that the proportion of the metabolizable energy of the food which was

utilized above the maintenance requirement, to produce gain, was decidedly less than that used below the maintenance requirement to prevent loss of tissue. The result is quite in accord with what we should anticipate. It seems altogether probable that a much less profound change is required to convert these resorbed products into forms suited to maintain the energy metabolism of the organism than is needed to convert them into the form of permanent tissue, especially fat.

In 1905 he wrote:

Clearly the percentage utilization (for body increase) is much less than the percentage availability (for maintenance).

In his publication of 1911, however, the following statements appear:

In previous publications we have expressed the belief, based in part upon experimental results and in part upon theoretical considerations . . . that the proportion of metabolizable energy capable of being stored up as gain, after the maintenance requirement is satisfied, is materially less than that available below the maintenance requirement to diminish the loss of energy from the body. The results of the present series of experiments fail to support that view. . . . In consideration of the greater weight attaching to the concordant results of the experiments of 1907, we are inclined to conclude that the percentage of metabolizable energy of the grain available was substantially the same above and below the maintenance requirement and that the discrepancies in the earlier experiments are perhaps due to errors.

In 1912 Armsby summarized the results of previous experiments as follows:

Such scanty data as are now on record seem to indicate that the two (availability of the metabolizable energy for maintenance and for production) are substantially the same in case of concentrated feeds, but that the available energy of coarse feeds below maintenance may be greater than their production values above the point of maintenance.

In 1915 Armsby analyzed the results of all his previous respiration calorimetric experiments (76 experimental periods) and recorded the following observations on the heat increment values of feeding stuffs:

The single results show a considerable range for the same or similar feeds not only with different animals but also, in some instances, between different periods with the same animal;

and regarding the effect of the amount of food consumed he remarked that

The data as a whole show about as many differences in one direction as the other and fail to give any distinct evidence of a greater relative increase of heat production on heavy as compared with light feed or on supermaintenance as compared with submaintenance rations.

On the basis of the foregoing analysis Armsby subsequently assumed that the heat increment of feeding is a rectilinear function of the amount of food consumed. This assumption is involved in Armsby's computation of the maintenance requirements of net energy (fasting katabolism) and in his calculation of the net energy values of feeding stuffs which are the basis of his feeding standard.

Nevertheless, it is evident from Armsby's latest publications, as well as from his outline of experiments which were concluded and published after his death, that he considered the question of utilization of food for maintenance and for production as not entirely solved, since, as late as in 1919, he stated:

> Whether the proportion which can be utilized is the same in the two cases (in maintenance and in productive feeding) it is perhaps too early to assert positively.

And the last series of experiments planned by Armsby included direct observations on the fasting heat production of cows for the purpose of checking his indirect computations of the fasting katabolism, and the underlying assumption that the heat production of an animal is a rectilinear function of the amounts of food consumed within the entire range between fasting and supermaintenance feeding.

In his attempts to explain the variability of some of his calorimetric results Armsby considered the various sources of error—both experimental and biological—and laid much emphasis on the possible effects of voluntary muscular activity. Early in his respiration work he proposed the idea that for comparative purposes the heat production of the experimental animals should be calculated to a standard day as to standing and lying in order to eliminate errors due to the differences in the rates of metabolism in these two positions. This idea was followed by him consistently, although the method of its application was changed from time to time. The logic of such a correction is obvious, but the determination of the actual difference in metabolism between standing and lying involves certain difficulties. This problem has received the attention of Forbes and associates, but at this time is considered as not solved in a completely satisfactory manner.

Another important factor which was recognized by Armsby as prominently affecting the utilization of metabolizable energy, and which must be carefully considered in experimental work on this problem, is the thermal environment. The need of controlled temperature conditions in respiration and balance experiments is well known. Much confusion can result when the environmental temperatures are below the critical point for the experimental animals. Certain confusion can also result when the surrounding temperatures are above the zone of thermal neutrality. The lower and upper limits of this zone, as affected by the plane of nutrition, and the fatness and coat of hair of the animal, remain to be definitely established.

Among other unsolved problems affecting the metabolizable energy of a ration and its utilization is that of accounting for the heat of fermentation. Fries (1922) studied this question, and demonstrated the effects of the application of corrections (Fries, Braman and Cochrane, 1924). These were of

considerable magnitude. His theoretical considerations have not been challenged. There is, at this time, however, no entirely satisfactory experimental basis for estimating the amount of the heat of fermentation.

Forbes' ideas. After a careful analysis of Armsby's published data and ideas, in deciding on a line of work which would serve best to promote the progress of the respiration calorimetric work initiated by Armsby, Forbes became convinced that before venturing on a course of routine determinations of net energy values of feeding stuffs it was imperative that more fundamental knowledge be secured regarding the various factors which affect such determinations. Consequently, much of the respiration calorimetric work conducted under the direction of Forbes since the year 1922 has been devoted to investigations of various conditions affecting the utilization of the energy of rations and of feeding stuffs. This work includes studies on the influence of (1) environmental temperature, (2) position of the animal, (3) plane of nutrition, (4) combination of feeding stuffs, and (5) the effects of individual nutritive deficiencies. The general trend of these investigations has been to show that net energy values of individual feeding stuffs can not be regarded as constants. Forbes (1933) summarized his views on this matter as follows:

> Evidence has been accumulating for many years, but especially during the past quarter century, which is in harmony with the conclusions of the writer and his associates (1) that, in a critical sense, foodstuffs can not be evaluated individually; (2) that net energy values of individual foodstuffs are fundamentally variable, and hence are not practicable standard measures of reference, and (3) that the most nearly logical, single conventional measure of whole nutritive value is the net energy of the nutritively complete ration."

According to Forbes

> an individual foodstuff expresses its normal and most characteristic nutritive value . . . only as it is a part of a ration which is qualitatively complete and quantitatively sufficient, for the conditions existing.

The plane of nutrition studies of Forbes, Braman and Kriss (1928, 1930) have shown conclusively that the relationship between the heat production and the quantity of feed eaten is as represented by a reversed curve, the curvature from fast to maintenance being prominent, and from maintenance to full feed being slight. The shape of the curve of heat production between fasting and maintenance has been explained, partly on theoretical grounds and partly on the basis of experimental evidence, as being due largely to the inclusion of dynamic effects of body nutrients katabolized, in gradually diminishing quantities, between fasting and the point of energy equilibrium. In other words, in the opinion of Forbes and his associates the fasting heat production includes dynamic effects of nutrients katabolized during fast and does not, therefore, truly represent the maintenance requirement of net

energy, and heat increment values of rations determined with respect to the heat production of fasting as a base are fictitious and do not represent the true energy expense of food utilization. Furthermore, it has been observed that the values so determined are subject to considerable variations depending on the quantity of the ration and on the sparing of body tissue constituents from katabolism.

In this light the relatively more constant heat increment values determined at supermaintenance planes of nutrition, with the heat production of approximare energy equilibrium as a reference base, are considered as more significant and more reliable comparative measures of the energy cost of utilization of rations than are heat increments determined with the heat production of fast as a base value.

That the individual nutritive values of feeding stuffs are not additive when the products are fed together has been observed throughout two generations of animal experimentation. A recent demonstration of this principle is a study by Forbes, *et al.* (1939) in which it is shown that the dynamic effects of protein, carbohydrate and fat as fed individually are not quantitatively significant with reference to these nutrients combined.

Also, many studies have been made of the specific effects of individual deficiencies in nutrition. Obviously, in the long run, no essential nutrient is more or less essential than any another.

An important result of a series of experiments initiated by Armsby but concluded by Forbes, *et al.* (1926) is that after an allowance has been made for the metabolizable energy requirements of maintenance, additional metabolizable energy is utilized for milk production more efficiently than for body increase.

Since directly determined heat increments of rations for maintenance are much less than for body increase, Forbes suggests that the maintenance requirements of animals be determined as the quantities of feed necessary for energy equilibrium, and that these requirements be expressed, for convenience, as equivalent quantities of whatever units are used in expressing the nutritive requirements for body increase.

Mitchell's ideas. Mitchell (1927) raised a question as to whether the purpose for which the food is used in the body is a factor in determining its net energy value.

According to this view the net energy value of any ration depends more on the relative rates of the supply of, and of the demand for, food energy by the animal than on the nature of its functional activities, except as the latter may determine the former. Hence, in productive feeding it may not be possible to make accurate separate assignments of feed (or metabolizable energy) for the different functions involved, since the possibility is recognized that, for example, the more rapid the growth of an animal or the greater its capacity for producing milk, the more efficiently will metabolizable energy be used for those purposes. This view would

regard feed assignment on the basis of requirements for production, to be added to a basic requirement for maintenance, as a method whose validity is not established, either rationally or evidentially. However, as a conventional system of assigning metabolizable energy to the various purposes for which it is used by the animal, it may be sufficiently accurate for practical purposes.

Forbes and associates agree with this expression, in part. They believe that there is no scientific means of separation of the heat production of maintenance from the heat increment of production, and that any such separation is necessarily conventional, but they have confidence in their experimental finding that metabolizable energy intake in excess of a conventional maintenance requirement was utilized with greater efficiency for milk production than for body increase.

Mitchell and Hamilton (1932) investigated the influence of the plane of nutrition on the energy metabolism of cattle, but obtained results differing from those of Forbes, Braman and Kriss (1928, 1930) in that, in the order of increasing feed consumption, there was a downward break in the curve of heat production at the level of two-fifths full feed, and a reversal of the trend by a break upward at the level of four-fifths full feed.

At a later date Mitchell (1934) advocated the theory that

the net availability of the metabolizable energy of all perfectly balanced rations is maximal for any imposed conditions of feeding, and that the metabolizable energy in rations equally well-balanced with reference to the nutritive requirements of the test animals are equally well utilized, regardless of the number or kinds of feeds combined in the rations.

Relative Energy Values of Feeds

In consideration of the difficulties involved in determinations of absolute nutritive effects of single feeds several workers (Morrison, 1937) (Kleiber, 1940) (Fraps and Carlyle, 1941) have attempted to determine the relative energy values of feeding stuffs, or replacement equivalents, by the comparison of standard rations containing certain reference materials with similar rations in which the test substances are substituted for the reference materials. The procedures proposed by these investigators differ in important details. They all have the apparent advantage of dealing with the nutritive effects of mixed rations instead of single feeding stuffs, but the ultimate evaluation of the tested feeding stuffs depends on the value assigned to the reference materials.

The procedure proposed by Morrison aims to evaluate the feeding stuffs in terms of net energy for maintenance and body increase, but the results are based principally on observations of live weight. Since the term net-energy has a well-established technical significance it should not be confused with values obtained from the results of feeding experiments based on live

weights unless and until it shall be shown that these results are the equivalent of gross food energy minus energy of excreta and heat increment.

The productive energy values determined and advocated by Fraps represent net energy values for body increase. Inasmuch as it was not practicable to give thorough consideration to Fraps's procedure in connection with the present report this should be made a subject of future study.

Kleiber's recently proposed partial nutritive equivalents represent both the protein and net-energy values of feeding stuffs for body increase, as compared with those of mixtures of casein and glucose the ratios of protein to energy of which are the same as those existing in the feeding stuffs under investigation. For practical application the casein-glucose equivalents are placed on the basis of cost. Judgment as to Kleiber's proposal should await research along lines which he suggests. Thus, the following are presented by Kleiber as

Theses recommended for test and discussion by a committee on evaluation of feeds;

(1) The difficulties of expressing nutritive values in absolute terms (such as net energy) are recognized. The efficiency of food utilization is affected by various conditions such as the plane of nutrition, nature of production, and the balance of the ration, especially the ratio of protein to energy.

(2) Feeds can be evaluated in relative terms as partial nutritive replacement equivalents.

(3) It is advantageous to measure relative partial nutritive values of feeds by pair or group trials against a standard reference substance.

(4) The reference substance as well as the food to be tested should be part of a standardized balanced ration.

(5) The attempts to measure the nutritive value of the reference substance in absolute terms such as net energy, i.e., to determine the efficiency of energy utilization as a function of various conditions is of great interest. It should lead to the prediction of the food effect under given conditions. This measurement is, however, not essential for the evaluation of feeds in terms of partial replacement equivalents.

(6) The partial replacement equivalent of a feed in terms of the reference substance should be established on the basis of equal production rather than equal food intake.

(7) Most natural feeds supply energy as well as protein and other nutritive essentials. Their energy and protein replacement equivalent can be measured simultaneously when they are exchanged against a mixture of a standard protein such as casein and a standard N-free nutrient such as glucose so that the net N:net energy ratio of the reference ration and the test ration are the same.

Examples of Basic Facts

The following tables contain illustrations of some of the facts which have been brought out in the foregoing survey of the work in respiration calorimetry, which have an important bearing on the problem of evaluation of feeds on the basis of net available nutrients. All data which are given in the tables are based on the published work of the Pennsylvania Institute of Animal Nutrition.

TABLE 1.—NET AVAILABILITY OF METABOLIZABLE ENERGY OF CORN MEAL WHEN ADDED TO DIFFERENT BASAL RATIONS

Food stuffs		Experiment and animal No.	Crude fiber in supplemented ration	Crude protein in supplemented ration		Energy balances		Net availability of metabolizable energy
Basal ration	Supplement			Total	Digestible	Basal ration	Supplemented ration	
			Per cent	*Per cent*	*Per cent*	*Cals.*	*Cals.*	*Per cent*
Oat straw+corn meal+molasses	Corn meal	261-A	19.4	7.3	3.9	−466	+2354	72.5
" " " " "	" "	261-B	19.5	7.3	3.1	−884	+1762	75.4
Timothy hay+corn meal	" "	261-A	19.5	7.5	4.3	+111	+2408	58.7
" " " "	" "	261-B	19.7	7.5	3.3	+444	+1368	55.8
Alfalfa hay+linseed meal +wheat bran	" "	261-B	18.8	19.5	15.0	− 31	+2325	66.7

The variability of the net energy value of a feeding stuff as caused by the associative effects of combination with other feeding stuffs in a ration is illustrated in table 1. This table shows that the net availability of metabolizable energy of corn meal varied from 55.8 to 75.4 per cent depending on the kind of basal ration to which it was added. The causes of such associative effects have not been determined.

Data in table 2 illustrate the effects of the plane of nutrition on the net energy value of a mixed ration when the fasting heat production is used as a base value for the determination of heat increments. The net availability of the metabolizable energy of a ration consisting of equal parts of alfalfa hay and corn is shown to vary inversely with rise in plane of nutrition, the extreme values being 94.9 per cent at the lowest plane and 63.7 at the highest plane. Whatever explanation may be given for this apparent effect of plane of nutrition, it is clear that this method of determination of net energy, i.e., the employment of the fasting heat production as a reference base, is not reliable for the purpose of comparing one ration with another when the rations are fed at different planes of nutrition.

The data in table 2 also show that at low planes of nutrition this method may give such high values for the net availability of the metabolizable energy (more than 90 per cent) that the heat increments involved can not be considered as real measures of the energy expense of food utilization.

Data in table 3 show the net availabilities of the metabolizable energy of seven different mixed rations used for maintenance, with the fasting heat production used as the reference base. The data show a range between 66 and 84.7 per cent and indicate that at approximately the same plane of nutrition the net availabilities of the metabolizable energy of different mixed rations determined by this method are subject to marked variation.

Of the seven rations compared, the one composed of equal parts of alfalfa hay and corn is shown to have the highest percentage utilization of the metabolizable energy—probably even higher than that obtained for a ration composed of alfalfa hay and a complex grain mixture. It has also been shown by Mitchell and Hamilton (1940) that the use of the fasting heat production as a reference base may yield lower heat increment values and higher percentage utilization of the metabolizable energy for less perfectly balanced than for more perfectly balanced rations. Furthermore, it has been observed that an extremely unbalanced nutrient product, such as glucose, may cause extremely small (in some cases negative) increases in heat production when fed to fasting animals.

A positive correlation between the nutritive balance and the net availability of the metabolizable energy of rations is not revealed, therefore, when the fasting heat production is used as the base value; and a prominent factor

TABLE 2.—NET AVAILABILITY OF METABOLIZABLE ENERGY OF A MIXED RATION (ALFALFA HAY+CORN MEAL, 1:1) AT DIFFERENT PLANES OF NUTRITION, DETERMINED BY THE USE OF FASTING HEAT PRODUCTION AS A BASE VALUE

Experiment and animal No.	Period	Energy balances	Net availability of metabolizable energy
		Cals.	*Per cent*
240–57	10	−3550	94.9
238–36	6	−3452	92.4
240–60	11	−3197	87.1
238–47	5	−3030	91.9
238–36	8	+ 218	81.4
240–57	2	+ 399	90.8
240–60	1	+ 403	84.6
238–47	7	+ 897	80.8
238–36	4	+2525	74.1
240–60	3	+2601	78.1
240–57	4	+3176	83.6
238–47	3	+3467	72.8
240–60	5	+3925	69.8
240–57	6	+4484	73.3
238–36	2	+4731	70.2
238–47	1	+5988	69.7
240–60	7	+5582	64.4
240–57	8	+6582	70.2
240–60	9	+7762	63.7

in this relation is probably that the efficiency of a ration to spare the katabolism of body substance is not in accord with its nutritive balance.

Data in table 4 illustrate the net availabilities of the metabolizable energy of mixed rations for body increase, determined with respect to the heat production of approximate energy equilibrium as a base. The results are given for seven different mixed rations fed at moderately different planes of nutrition, as indicated by the energy balances.

In contrast to tables 2 and 3 the results in table 4 are relatively uniform. In spite of the fact that the planes of nutrition differed significantly, the net availabilities of the metabolizable energy of the different rations show a marked similarity. Evidently the plane of nutrition does not affect the net energy values of a ration for body increase to any great extent when the heat production of maintenance is used as the reference base. This method

TABLE 3.—NET AVAILABILITY OF METABOLIZABLE ENERGY OF MIXED RATIONS FOR MAINTENANCE, DETERMINED BY THE USE OF FASTING HEAT PRODUCTION AS A BASE VALUE

Maintenance rations	Experiment and animal No.	Period	Crude fiber	Crude protein	Energy balances	Net availability of metabolizable energy
			Per cent	*Per cent*	*Cals.*	*Per cent*
Alfalfa hay+grain mixture (2:3)	221D–886	3	20.0	14.9	+854	83.2
	221F–874	2	20.3	14.1	+151	77.7
	221F–887	2	19.3	14.2	+277	75.3
Average						78.7
Silage+oats (1:0.67)	237–254	8	15.8	11.7	+130	75.4
Alfalfa hay+oats (1:1)	237–36	12	22.8	14.3	+104	75.9
" " "	237–47	13	23.1	14.4	+710	79.2
Average						77.6
Alfalfa hay+corn meal (1:1)	238–47	7	18.0	13.5	+897	80.8
" " " "	238–36	8	18.0	13.5	+218	81.4
" " " "	240–60	1	18.4	12.2	+403	84.6
" " " "	240–57	2	18.4	12.2	+399	90.8
" " " "	241–17	5	18.8	12.8	+522	85.8
Average						84.7
Oat straw+corn meal+molasses	261–A	3	24.4	7.0	−409	66.6
" " " " "	261–B	4	24.4	7.0	−639	67.6
Average						67.1
Timothy hay+corn meal	261–A	7	24.1	7.1	+212	71.5
" " " "	261–B	8	24.3	7.0	−275	75.7
Average						73.3
Alfalfa hay+wheat bran+linseed meal	261–A	11	23.3	22.1	+607	65.3
" " " " " "	261–B	12	23.3	22.1	−305	66.7
Average						66.0

TABLE 4.—NET AVAILABILITY OF METABOLIZABLE ENERGY OF MIXED RATIONS FOR BODY INCREASE, DETERMINED BY THE USE OF MAINTENANCE HEAT PRODUCTION AS A BASE VALUE

Rations	Experiment and animal No.	Periods compared	Crude fiber	Crude protein	Energy balances		Net availability of metabolizable energy
					Basal ration	Supermaintenance ration	
			Per cent	*Per cent*	*Cals.*	*Cals.*	*Per cent*
Alfalfa hay+grain mixture No. 4[3] (2:3)	221D–886	3 and 2	20.0	14.9	+ 854	+4358	56.1
" " " "	221F–874	2 and 1	20.3	14.1	+ 152	+3480	61.2
" " " "	221F–887	2 and 1	19.3	14.2	+ 277	+2987	57.1
Average							58.1
Alfalfa hay+corn meal (1:1)	238–47	7 and 3	18.0	13.5	+ 897	+3467	56.4
" " " "	36	8 and 3	17.9	13.4	+ 218	+2525	56.7
" " " "	47	7 and 1	18.0	13.5	+ 897	+5988	58.9
" " " "	36	8 and 2	18.0	13.5	+ 218	+4731	57.9
" " " "	240–60	1 and 3	18.4	12.2	+ 403	+2601	65.1
" " " "	57	2 and 4	18.4	12.2	+ 399	+3176	68.1
" " " "	60	1 and 5	18.4	12.2	+ 403	+3925	55.5
" " " "	57	2 and 6	18.5	12.2	+ 399	+4484	56.2
" " " "	60	1 and 7	18.5	12.3	+ 403	+5582	52.5
" " " "	57	2 and 8	18.5	12.3	+ 399	+6582	57.7
" " " "	60	1 and 9	18.5	12.3	+ 403	+7762	55.2
Average							58.2
Alfalfa hay+grain mixture No. 2[1] (1:2)	209–F	2 and 1	14.9	13.4	− 95	+2147	63.2
Mixed hay+corn meal (1:1)	211–G	2 and 3	13.4	10.4	−1340	+6088	58.8
Mixed hay+hominy chop (1:1)	211–D	2 and 3	19.5	10.8	− 380	+7592	62.4
Alfalfa hay+grain mixture No. 3[2] (1:2)	217–J	1 and 2	13.5	14.3	+1028	+8463	56.6
Red clover hay+corn meal (1:2)	220–K	3 and 4	12.1	10.2	+ 482	+4608	58.6

[1] Grain mixture No. 2—60 parts cracked corn, 30 parts crushed oats and 10 parts linseed meal.
[2] Grain mixture No. 3—2 parts wheat bran, 6 parts corn meal and 1 part cottonseed meal.
[3] Grain mixture No. 4—30 parts wheat bran, 30 parts ground oats, 30 parts corn meal and 10 parts linseed meal.

is, therefore, more reliable for the comparison of rations than is the method on which tables 2 and 3 are based.

The similarity in the results for the different rations might be explained on the basis of one of the following assumptions: (1) The rations are of similar type. (2) The results for mixed rations are composites of the values of their components and are, therefore, naturally subject to smaller variation than are the values for the individual components. (3) The rations were all fairly well balanced, and in such rations the utilization of the metabolizable energy for body increase is approximately the same regardless of the kinds of the component feeding stuffs.

Of the three suggested explanations the last one is the most plausible. There is considerable indirect evidence in the literature in support of this hypothesis and it deserves further study. If the validity of this hypothesis can be definitely established it would be possible to assume that the net energy of well balanced rations is proportional to the metabolizable energy.

General Conclusions and Recommendations

The foregoing considerations relative to the problem of determination of net-energy values of feeds and rations lead to the following general conclusions:

1. The net energy conception is a correct basis of expression of the ultimate energy value of a ration, and commends itself especially for purposes of fundamental research under conditions of intensive and adequate experimental control. However, the net-energy value of a ration is not a constant, but is subject to considerable variation, depending on the experimental conditions and the methods of determination. The directly observed net energy value of a ration used for maintenance is different from its value as used for body increase; and the latter is different from the value of the ration as used for milk production. Also, the net energy value of a ration, and its significance, depend on the base value of heat production used in its determination. Further, the conditions of experimentation for the determination of net energy values are most exacting, and the necessary control of physical activity, thermal environment, and endocrine functions may not be successfully accomplished.

2. The net availability of the metabolizable energy of a ration is prominently affected by the plane of nutrition when the fasting heat production is used as the base value in determining the heat increment. This fact has been interpreted as resulting, in the main, from the sparing effect of the food in relation to the katabolism of body tissue nutrients. In this sense heat increments based on the heat production of fast do not express the real energy expense of food utilization.

3. Energy maintenance requirements are directly determined by balance experiment as the quantities necessary for equilibrium; and since the observed heat increments of rations for maintenance are decidedly less than for body increase, the effect of this difference is to render net energy values for maintenance higher than for body increase. For convenience, however, net energy requirements for maintenance may be arbitrarily expressed in terms of net energy for production; but, whatever the plane of nutrition, the energy required for equilibrium will be increased as the environmental temperature is either higher or lower than the zone of thermal neutrality. In other words, under these conditions the total metabolizable energy becomes net energy.

4. The utilization of the metabolizable energy of a ration for body increase, determined from a comparison of maintenance with supermaintenance planes of nutrition, is not much affected by the plane of nutrition within fairly wide limits above maintenance. This is the method of choice, therefore, for comparison of rations on the basis of net energy for production.

5. The utilization of the metabolizable energy of a ration depends much on the nutritive balance of the nutrients, and the net energy of a ration is not necessarily equal to the sum of the separately determined net energy values of the component feeding stuffs.

6. The net energy values of individual feeding stuffs are fundamentally variable in the sense that their values depend to a considerable extent on the combination in which they are fed with other feeding stuffs. The associative effects of combination are unpredictable in the present state of knowledge.

7. There is some evidence to the effect that in nutritively complete rations the utilization of the metabolizable energy for body increase and also for milk production approaches constancy. This subject deserves further investigation.

8. The question of the net availability of the metabolizable energy of rations and of feeding stuffs under various conditions is not yet completely solved and should be investigated further.

9. The methods of determination of production and replacement values of feeding stuffs which have been advocated by Fraps, Morrison and Kleiber should be given further consideration.

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RECORD OF PROCEEDINGS OF THE 35TH ANNUAL MEETINGS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

THE Meetings were held at the Hotel Sherman in Chicago on December 1 and 2, 1942.

Abstracts of most of the scientific papers presented were published in the JOURNAL OF ANIMAL SCIENCE, Vol. 1, pages 341–360. Because of emergency conditions abstracts could not be obtained of a few of the technical papers and all of the papers presented at the general sessions, for advance publication. Space limitations prohibit publication of a major portion of the program material not covered by advance abstracts, but some highlights are presented in the following pages, along with a record of the business conducted and other items of interest to the membership.

Attendance was better than anticipated. Approximately 175 members and guests were present, and all general sessions and sectional meetings were well attended, considering the handicaps placed on attendance by the conditions of the present emergency.

PRESIDENT'S ADDRESS

R. M. BETHKE

Ohio Agricultural Experiment Station

THIS, the thirty-fifth annual meeting of our Society finds our country in alliance with other nations of the world actively engaged in a war to preserve the principles of a free democracy. I am certain that every member of this Society is familiar with, and cognizant of, his responsibility in the war program.

As we come together this morning many familiar faces are missing. Many of our members are in active military service. Others have dropped their regular work temporarily and assumed important positions in essential though non-military phases of the war program. Many others are actively engaged in the defense program in one way or another on the home front. I wish to pay tribute to those members of the Society who are unable to attend this meeting because they are engaged in military service or other work essential to the war program.

Proper food is fundamental to the maintenance of a strong armed force and a proper home defense. Livestock producers have a major responsibility in the production of this food. They have been asked to increase their production of meat, milk, and eggs so that the armed forces of the allied nations and the civilian population of this and other countries may be adequately fed. As originators of many of the methods followed by livestock producers

and as leaders of thought in livestock production, the members of this Society have a great responsibility in helping to carry out the production goals.

It behooves every member of this Society to ask himself—What can I do? How can I be of greatest help in the war program? It is essential that we lay aside any petty jealousies, personal bickerings or grievances and work more energetically and cooperatively than ever before so that no one can say of us, "Too little and too late."

In opening the meeting, I think it is only proper to take a few moments and give you a brief accounting of my office and lay before you certain facts concerning the Society.

The past year, as you might anticipate, presented several problems with which your officers and executive committee had to deal. One of the major problems concerned the annual meeting. Shortly after the original announcement that the Board of Directors of the International Livestock Exposition had voted not to have a livestock show this year, I received many letters from our members asking what action the Society was going to take in regard to an annual meeting. After consultation with members of the executive committee and past presidents of the Society, it was decided to withhold any final decision until sometime later. In the latter part of August I again contacted members of the executive committee, past presidents, and heads of animal husbandry departments throughout the country on the advisability of having an annual meeting. Out of the 42 replies received to my inquiry, 30 definitely favored having a meeting, 6 were not in favor of having a meeting, and the remaining 6 were more or less non-committal. On the basis of this vote, it was decided to have an annual meeting so as to coincide, as in former years, with the Livestock Show and the meetings of the U. S. Livestock Sanitary Association.

You will note that the program arrangement is somewhat different from that followed in former years. This was done in order to give more or less uninterrupted consideration to the war-time livestock production problems and yet afford an opportunity for the presentation of current research studies. It was impossible to have as many sectional meetings as we have had in the past. Some of these sectional program chairmen had made arrangements for a meeting, but when they were appraised of the problem by the Secretary they most heartily agreed to cancel their sectional meeting. I wish to compliment all individuals for the fine spirit they showed in setting up this year's program.

Some of you have probably wondered why no provision has been made this year for an honor guest of the Society. The majority of the members of the executive committee and the past presidents of the Society felt that the

Society should forego the customary honor guest presentation this year, because of the uncertainties underlying an annual meeting. Because of the necessity for making arrangements several months prior to the meeting, many were of the opinion that it might prove embarrassing to the Society to postpone the portrait presentation of the selected honor guest in case the meeting might have to be cancelled.

While attending the meetings of the Federation of the American Societies of Biology and Medicine in Boston, Mass., this spring I was invited to discuss with members from the American Dairy Science Association, Poultry Science Association, American Veterinary Medical Association, and the United States Livestock Sanitary Association (1) the advisability of asking the National Research Council to appoint a committee on animal health and productive efficiency and (2) the formation of an inter-association committee to act as a liaison committee between the respective associations in the interest of better public service. These two matters were taken up with the members of the executive committee, who approved both proposals. Dr. W. V. Lambert, Associate Director of the Indiana Agricultural Experiment Station, was appointed to represent the Society on the inter-association committee.

The first year's issues of the Society's new journal have appeared on schedule. The editor and editorial board are deserving of commendation for their good work. Many favorable comments have been received concerning the new quarterly publication. It appears that the JOURNAL is meeting a long-felt need. To develop a strong Journal will require not only a rigid editorial policy but also the building up of a large subscription list. Since the JOURNAL OF ANIMAL SCIENCE is the official publication of the Society, it is the responsibility of every member to assist in building a strong, worthwhile publication.

The Society is growing. Many new members have been added during the year. We need additional members if we are to maintain a sound financial position, especially during the next few years. I am certain that there are many qualified prospective members who would be interested in the Society if they were properly approached.

The task of administering the business affairs of the Society is growing each year. The time is rapidly approaching when part of the income will have to be used to pay for some of the administrative expense. Every member should be willing to accept responsibility to assist in building for a still stronger Society.

THE RESPONSIBILITY OF RESEARCH WORKERS IN LIVESTOCK PRODUCTION IN THE WAR PROGRAM[1]

NOBLE CLARK[2]
University of Wisconsin

THE need for planes and other materials of war is hardly more urgent than the need of our Allies and our own fighting forces for food. Each soldier requires twice as much to eat as an average civilian. Millions of men in the uniforms of the United States, Great Britain, Russia, and the other United Nations are depending upon American farms to supply the food they must have if they are to drive the tanks, fly the planes, and shoot the guns against the Axis and the Japs. Likewise the millions of our civilians who mine the metals, who operate the railroads that transport the ores and the finished manufactured goods, and those who labor in our war industries, must eat before they can work. The meats, cereals and other foods must be provided before the raw products of industry can even be started on their way to the factories. It can truly be said that food is a first line of defense, and the flag is on every American farm that is doing its part in furnishing the food products upon which the whole war effort depends.

But I imagine some of you are saying to yourselves, "We grant all this, but what has it to do with research in animal production in war time? This is an emergency when all-out and immediate farm production is called for. Why talk about research to find new facts when what we need is the widest possible utilization of the information we already have? Why should not every research man volunteer as an extension worker, and thus insure the wider adoption by farmers of the improved practices which research has already discovered?"

Many of you have had thoughts like these. Most of you have already modified your customary schedules, and are giving generously of your time and energy to the solution of the immediate problems on livestock farms that have been created by the war. None of us expects or wants our research to go along on a basis of business as usual. We are as anxious as other citizens to make our contributions where they will help most in winning the war. Hardly a week goes by but what some member of our station staff comes to me for personal counsel as to whether he should not drop his research and get into some line of war work. It is easy to understand the instincts which prompt these inner questionings by young men eager to do their patriotic duty. My responsibility is to help them to see the national

[1] Extracts from an address delivered December 1, 1942 before the Annual Meeting of The American Society of Animal Production, Chicago, Ill.

[2] Associate Director, Wisconsin Agricultural Experiment Station, Madison.

and international situation in its entirety, and to suggest that they use their reasoning faculties as well as their impulses and emotions.

In the first place, I tell these men that every citizen should have the privilege of serving in the armed forces, or in work directly connected with the making of armament and ammunition, if he really craves such service above all else. All of us in civilian life owe too much to the men in uniform to permit us ever to question the value and need of the armed services. I shall never tell a man not to go into the army or the navy. But in these days of total war it needs to be emphasized that the welfare of all of us, and the efficiency and success of the whole war effort throughout the entire world, are directly dependent on millions of civilians each doing his essential part in the global struggle. There are hundreds of ways of rendering patriotic service to one's country, and harnessing science to the task of increased production of livestock is not by any means the least important. Few men in this generation have a larger opportunity and obligation to use their special training and experience to serve their nation and the world in this greatest of all wars.

The year of 1942 has been the most favorable for agricultural production that this nation has ever seen. Overall production of crops and livestock exceeds all previous records. Farmers and their families have worked skillfully, and for long hours, to make this marvelous achievement possible. Maintenance of the 1942 level of farm production will be difficult. The food demands of our armed forces and for lend-lease are constantly increasing, and each week sees new thousands employed in war work in our factories who must look to our farmers to supply them with generous quantities of nutritious foods to enable them to keep their vigor and efficiency on high levels. American farmers face the largest responsibility ever placed upon them.

Before another six months have passed we probably will be rationing many foods in addition to sugar, meats and dairy products, There will not be enough of the more nutritious foods to go around, even if American farmers turn out as much production in 1943 as in 1942. The possible effects of this food shortage on our national economy, and on the world-wide war effort, are not pleasant to contemplate. Now, as never before, the men on the land have a right to ask the men of the laboratory and the feed lot to supply every aid which science is capable of giving.

The old facts, already in the text books, bulletins and circulars, will not be enough. The war has created a host of new problems. No one is as well able to meet these new situations as those skilled in research. No one else has their detailed knowledge of all that has been learned in laboratories and feed lots throughout the entire world since the beginning of our relatively young science of animal production. No one else is as competent

to determine which problems can be decided with reasonable accuracy with present imperfect information, and which situations require at least preliminary trial or research before recommendations can safely be made to the general farm population. No one else is so accustomed to taking the long view, and hence so capable of initiating now the fact-finding programs to answer the still more urgent problems that are almost certain to confront American farmers in 1944.

It now seems certain that we are going to be faced with the need for feeding a very large part of the civilized world. As our armies liberate the occupied nations, we must take over the task of feeding those who have not already been killed by starvation or disease while under the Nazi yoke. The very prospect that our armies will bring this food is keeping hope and courage in millions of victims of German aggression. Herbert Hoover has pointed out that it will be a race against disaster after the Germans are beaten and sent home. We must get the food promptly to the liberated peoples to prevent not only starvation and disease, but revolution and its attendant complete breakdown of all economic activities, because hungry people cannot and will not support a government that does not feed them. The products of American farms will have it in their power very largely to determine the kind of government the peoples of Europe will have after the armistice. Certainly it can be said that the material well-being of most of Europe during the first 18 months after the armistice will be measured almost directly in terms of how much, and what kind, of food we can deliver quickly to the millions who must have it to live and to rebuild their own food producing facilities.

This is a time for facing facts realistically. American agriculture faces more than a 12 months' emergency. It must find ways of meeting extraordinary demands that are almost certain to grow even larger in 1944, and perhaps still larger in the years after that. We must therefore make our plans for the long pull, not just for 1943. This means more and better research, because present methods will never enable us to meet the goals that are being set for us. The conclusion is inescapable that research in animal production is today an enterprise of first importance that urgently needs the best that any of us can give. Ours is an undertaking that concerns the welfare of all the people, and every day the demands being made upon us are more numerous and more difficult.

The present situation calls for newer and more effective research than much that has been conducted in the past. We do not have the time to repeat feeding trials for five successive years before conclusions are drawn. Such a procedure increases the accuracy of our findings, but the war, and the immediate post-war crisis, will be over before 1947, we all hope. We need the

aid of science in answering questions that must be met in 1943 and 1944

What kind of questions are we likely to be asked? I shall list some examples. Others, even more urgently important, are likely to occur.

With two years' supply of wheat on hand, and an acute shortage of industrial alcohol for the manufacture of explosives, the government is urging distillers to use wheat instead of corn in their industrial fermentations. There will soon be thousands of tons of wheat distillers' dried grains available weekly for livestock feeding purposes. What are the grains worth? How can they best be combined with the available forage and other concentrates? Extension specialists want the research men to give their best educated guess until we have some results from actual feeding trials that will serve as a more accurate guide.

Evidence is accumulating that vitamin A is much more frequently a limiting factor in the nutrition of dairy cattle than is commonly appreciated. The winter feeding season immediately ahead of us promises to supply painful proof of this lack. Much of the hay produced in Wisconsin last summer was so badly injured by rain during the haying season that it lost a major part of its vitamin A. More than half of our corn silage was harvested after the September frost, and hence has practically no vitamin A. On thousands of our farms we therefore have little vitamin A in our forage. It is hard to construct a practical ration that will supply adequate vitamin A in the concentrate part of the ration alone. We must therefore expect decreased milk production and various kinds of breeding troubles next February and March.

The immediate need is obviously to build grain mixtures that will carry the maximum of vitamin A. This the research man can do in cooperation with the extension specialists. But the more important research task is to make the plans now that will prevent the recurrence of this acute shortage of vitamin A in dairy cow rations a year from now, and all the years into the future. Is this objective best attained by urging every livestock farmer to have at least half his silage in the form of grass silage? Or should we recommend to farmers that they cut their corn for silage a week or ten days earlier than has been their custom, and in this way secure a higher content of vitamin A, even though it means an appreciable reduction in the yield of total digestible nutrients per acre of corn? There may be still other alternatives, but it is a problem that only the highly skilled livestock nutrition man can wisely answer, and perhaps he will need to undertake some short-time rough and ready research on scores of farms to learn how the various procedures actually work out under practical farm conditions.

Of one thing I am very certain. The stakes are enormously large. Milk production in Wisconsin this winter is going to be scores of millions of pounds less than it would be if we had adequate vitamin A stored in the hay mows and silos of our dairy farms. The research man who can work out

methods of preventing the recurrence of this vitamin shortage may thereby make possible in future years additional food supplies that will protect the health, and perhaps even save the lives, of literally thousands of hungry Greeks, Norwegians, Jugoslavs or Belgians. The time has come when livestock research is not alone a matter of animals and feed materials—it is the foundation of health, and life itself, for millions of people.

The urgency of the times should make us courageous to try novel and unusual remedies for the new problems the war has brought. There is nothing traditional or conventional in the way Henry Kaiser builds a cargo boat in a fraction of the time previously thought necessary. We, too, must find short cuts. We must break out of our customary ways of thinking and acting. We need new and better ideas in livestock research just as we do in the design of airplanes and tanks. Only new and better ideas can possibly permit American agriculture to meet the mounting demands for food. Who has a larger responsibility for supplying these new ideas than those who have had intensive training and experience in livestock research?

Russian research workers during the past two decades have amazed scientists in other countries. Artificial insemination of farm animals had long been known as a possibility, but the Russians made it work with thousands of animals under practical farm conditions. Now we in the United States have copied their methods, and the practice promises to revolutionize the dairy industry in much the same way as the baby chick business a generation ago made possible advances in the poultry business as much in ten years as had previously occurred in ten thousand years. Russian methods in plant breeding have been just as spectacular. The youthful vigor and unorthodoxy of Russian science may offend our conventions, but I admire their fresh enthusiasm and courage. We could use some of their spirit in attacking the problems that lie ahead of us.

The history of agricultural research records many brilliant contributions by chemists. With no desire to make invidious comparisons, it seems to me chemists have been able to make so many spectacular advances in science because they were willing to try the wholly new and the unorthodox. They have taken a small amount of material in a test tube or beaker and have tried all kinds of mixtures and treatments until they found the fortunate combination that has opened up great new vistas in thinking and practice. I wonder if livestock production men could not take a leaf from the experience of chemists. Please do not misunderstand me. I do not want to belittle well planned and accurately executed experiments. Quite the contrary, they have an important role and I believe in them. But is there not also a need for simpler and more rapid explorations into the great body of unknown information?

The plant breeders have given the livestock men something to shoot at.

In 1942 the U. S. government estimates that the use of hybrid seed corn increased the nation's corn crop 300,000,000 bushels, or enough to produce 3,300,000,000 pounds of pork. It's time we found a way of showing that livestock research is doing as much to increase livestock production as these plant men who make no claim of knowing anything about animals.

Livestock research men, perhaps more than any others in agricultural research, need to learn to work closely in cooperation with their fellow scientists in related fields. Few problems in animal production fall neatly in a single scientific discipline. The forage or grain you are evaluating in the field lot are influenced by the soil on which they were grown, and by the practices followed in growing and harvesting the crop. The engineer played a part in all this as well as the soils specialist and the agronomist. When you evaluate the data from your feeding trial the men in farm management and agricultural economics have their contribution to make. And so on down the line. To me the conclusion is obvious that in livestock research Kipling was wrong. He does *not* travel fastest who travels alone. Too often the American farmer is confronted with isolated facts secured by scientists, each working in their own special fields. What the scientists could not, or did not, coordinate at the research center, the farmer has been asked to do on his farm. This seems to me unwise, particularly in wartime when we cannot afford costly trial and error methods.

Today the need is for synthesis, as well as analysis, at the research center. In the field of livestock production the research members of the American Society of Animal Production have major responsibility for such synthesis. I urge that when you go back to your respective institutions you explore the possibilities of doing even more of this integrating and coordinating than you have in the past. Research does not need a unified command that compels teamwork. On the contrary it is most efficient when by democratic procedure we combine forces voluntarily to advance towards the goals that all of us seek. The army, navy, marine corps and air corps are setting all of us a brilliant example in teamwork. We must not be satisfied with any less achievement in our civilian endeavors.

LIVE STOCK IN WAR-TIME BRITAIN

J. A. SCOTT WATSON[1]
British Embassy

FOR reasons of soil and climate large parts of Britain are better suited for pasture than for cultivated crops. Moreover, because of the density of population, the British farmer has an excellent market, almost on his door-

[1] Agricultural Attache, Washington, D. C.

step, for milk, meat, poultry and eggs. If we remember also the low world prices of grain and other feeds in the years before the war we have most of the explanation of the general set-up of Britain's peace-time agriculture. The improved farm-land consisted in 1939 of nineteen million acres of grass and thirteen million acres of cultivated crops, while the annual importation of feed amounted to some eight million tons.

With the outbreak of war and the steadily increasing demands upon shipping, imports of corn, barley, etc. declined rapidly; they had practically ceased after eighteen months of war. Imported feed resources then consisted of about two million tons of by-products, mainly mill-feeds derived from imported wheat and oil-meals from imported seeds. Somewhat later came the further loss of most of the finer mill-feeds arising out of the change from 72 per cent to 85 per cent extraction in the flour-milling industry. Still more recently some home-produced oats and barley have been diverted from animals to human beings.

Partly to make room for essential food crops (wheat, potatoes, sugar-beets and vegetables), and partly to secure more oats and beans for winter milk production, it has been necessary to encroach heavily on the pasture area. By 1942 about one-third of the original acreage had been broken up and cropped.

Naturally there have been great efforts to raise the productivity of the remaining grassland and to increase crop yields. Among many measures having this object the most important has been the largely increased use of nitrogen fertilizers, made possible by the large expansion of the synthetic industry and the prohibition of exports. Very fortunately also, the United States was able to replace North Africa as a source of phosphate fertilizers after the fall of France. But heavier use of fertilizers and the other available measures could not have been expected to make good the double loss of feed and hence it has been necessary to follow a systematic and progressive policy of livestock reduction, and its distribution among the several classes of livestock were obviously matters that required most anxious consideration.

Essential horses, whether on farms, in cities or in mines, had obviously to be fed. Again, in view of the overall scarcity of "health foods" the relative efficiency of the different farm animals as health-food producers was a primary consideration; nutritionists were unanimous that, on this ground, the dairy cow must have priority over all other classes of stock. Pigs and poultry had been most largely dependent on imported feed, and in any case they could not be allowed to compete with human beings for the limited supplies of grain. Hence they had to suffer the most severe reductions. Finally, as between beef cattle and sheep there were two main arguments in favor of cattle—viz. that sheep could be more rapidly increased when

normal conditions returned, and that beef cattle could be more largely maintained on straw, second-quality hay, beet tops and other by-products.

These considerations explain the changes that have actually been made. Draft horse numbers have been almost maintained. Milking cows have been somewhat increased, and replacements now available will permit of further expansion. Beef cattle numbers have fallen only slightly. Sheep are down by more than twenty per cent, and it is naturally the lowland (as distinct from mountain) breeds that have suffered. Numbers of breeding sows are somewhat below half the normal.

These changes have been made almost entirely by the voluntary action of the farmers themselves, who have been kept constantly informed about feed prospects. A feed rationing scheme, which has been in operation since February 1941, is based on the principles (1) of making adequate allowances for all horses and milking cows, (2) of providing rather liberal amounts of calf meals, in order to release milk for human consumption, (3) or providing limited amounts of protein supplements for lambing ewes, of feeds suitable for farrowing sows, and so on, (4) of taking care of pure-bred herds, and (5) of distributing the remaining balance (which of course has progressively diminished in quantity) between commercial pig and poultry producers.

Farmers, of course, are still free to crop some part of their farms as they think fit, and have so far been allowed the free disposal of their own supplies of oats, field beans, fodder roots, hay and straw. On the other hand all millable wheat, all barley, all eatable potatoes and all sugar beets must be sold.

In the spring of 1941 a scheme was drawn up for the compulsory slaughter of surplus cattle, but this has never been used except for the purpose of eliminating unthrifty animals. At this same period feed supplies were shrinking more rapidly than had been anticipated and, with the introduction of feed-rationing, some farmers were obliged to kill off laying fowls and to sell for slaughter unfinished hogs. Otherwise it may fairly be claimed that the reduction of numbers has been a systematic process, carried through with a minimum of waste.

Certain other changes have been made to adapt the industry to the necessities of war. Cattle and sheep prices have been so set as to encourage only a very moderate degree of finish; for instance the most profitable finish for cattle is that which gives a carcass percentage of about fifty-seven. The reasoning behind this is that the lamb or steer is less efficient than the hog in converting grain into edible fat. On the other hand hog prices are so devised as to encourage marketing at heavy weights (up to 300 lb.) partly because there is an increased need of fat and partly because the large hog can use a high proportion of unmarketable potatoes, household waste and other by-

products. Most cities have organized the collection of household waste, and many now operate sterilizing and concentrating plants.

Among other efforts to eke out feed supplies may be mentioned the widespread development of grass silage, and the considerable amount of wheat and barley straw that is now treated with caustic-soda in order to dissolve away the lignin fraction and so improve its digestibility. So far there has been no object in using urea as a protein substitute to balance the greatly reduced supplies of grain and other starchy materials.

Livestock farmers have naturally had their share of labor difficulties, but key men have generally been exempted from military service or have been deferred until substitutes could be trained. The greatest source of efficient substitute workers has been the Womens Land Army which is now fully fifty thousand strong and whose members are doing fine work in the cow-sheds and feed lots, as well as in the fields.

SUMMARY OF THE MINUTES OF THE THIRTY-FIFTH ANNUAL BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

A. D. WEBER, *Secretary*

The thirty-fifth annual business meeting of the Society was held on December 2, 1942, at 2:00 p.m., in the Hotel Sherman, Chicago, Illinois. R. M. Bethke, president of the Society, presided.

The Treasurer's report showed a balance of $4,880.09. The Secretary's report indicated that 496 members had paid their 1942 dues. During the year 90 new members were added, and 177 non-members subscribed to the JOURNAL OF ANIMAL SCIENCE.

A special auditing committee consisting of E. F. Ferrin and W. P. Garrigus reported that the accounts of the Treasurer were examined and found to be correct.

Unanimous approval was given to the report of the Committee on Investigation. This report stressed the importance of continuing long-time fundamental investigations during the present emergency.

Approval was also given to recommendations of the Special Committee on Pasture and Range Investigations, relating to the possibility of increasing livestock production through more efficient utilization of our present pasture acreage.

The following recommendations of the Special Committee on Evaluation of Feeds were approved by unanimous vote, and ordered published in the JOURNAL OF ANIMAL SCIENCE:

1. That the committee appointed by the executive be reduced to three members, with one retiring annually, who will be replaced by a new appointee.

2. The duties of this three-man committee will be: to stimulate and where possible arrange for research on the problems of methods of evaluating feedstuffs; to coordinate such data as may become available through the efforts of different laboratories; and to arrange for the presentation of the results of specific research on the problem at suitable regular sessions of the Society. It is believed that acceptable papers bearing on this problem would form a legitimate part of the nutrition session program in any year when available and would constitute contributions from this proposed committee.

3. In any given year a working committee would be established, consisting of the three-man group, together with all individuals who during that year were actively engaged in some research on the problem of feed evaluation. This group of auxiliary members would be named by the three-man committee. It seems logical that they should meet annually and discuss ideas, ways and means of furthering the work.

This plan is intended to obviate the problem of a working committee operating without funds with which to support research which it wishes done. It depends for its success on finding one or more laboratories interested enough in some phase of the problem to undertake it on their own funds. The research would be their own, and be reported by them as such. It provides for presentation of new data to the members of the Society where regardless of its unanimous approval of the committee, it can be discussed and accepted for what value it has. Eventually, the accumulated findings could be compiled for publication if desired

A portion of the report of the Special Committee on Registration of Animals Produced by Artificial Insemination and Recognition of New Breeds also is included as a part of this summary as a result of action taken by the Executive Committee, to whom the report was referred. It is intended that this portion of the report be given further consideration at the 1943 annual meeting:

REPORT ON RECOGNITION OF NEW BREEDS

The Committee might function as a clearing house for information, set up standards, and present an approved list of livestock breeds in America.

This presents real difficulties and the membership should be cognizant of the action of the Society on recommendation of its Committee on Investigation at the 1940 meeting as follows:

The Recognition of New Breeds. This committee recognizes the need for some agency that can serve in the capacity of setting up standards for new breeds, but is of the opinion that it is not the function of the Society to do this. Therefore, it declines to voice a recommendation for any agency that would act in this capacity.

Science has not succeeded so far in finding a criterion for grouping domestic animals within their species. Therefore a breed is extremely difficult to define beyond its recognition as a subgroup within a species.

In spite of these difficulties, the animal breeder has a fairly definite opinion on the subject. He considers breed as something established and for a long time has been giving breed names to various groups of animals. These animals are entered in herd books and on breed is founded almost the whole trade in animals for breeding purposes. When, however, grouping into breeds is considered for a whole country or the entire world, serious difficulties arise because of the changing environment.

This would require a statement of the minimum requirements for the breed name to be added to the approved list of the Society. We might tentatively define the term purebred as an animal of a particular breed that meets the registration requirements of the specific breed

association. Breed descriptions are criteria for the probable purity of the breed of any given animal. They are founded in part on properties connected with utility, i.e., production, reproduction, and vigor. Many of the properties on the other hand have no connection with the production value of an animal and as far as possible these should be minimized.

Your Committee would like to refer to new strains of swine that are in process of development in this country as a result of hybridization between certain strains of the American breeds and the Danish Landrace. It might be advantageous if something could be worked out with existing breed associations whereby, let us say a new strain developing from the Poland China-Landrace cross might be carried as a separate strain within the Poland China breed. Every effort should be made to preserve these strains now being produced and safeguard them against dilution. It might show the way whereby new desirable genes might be introduced in our existing breeds. If it could not be worked out with existing breed associations a new general registry association might take over the responsibility for registering animals in line with standards adopted by this association. Perhaps a precedent for such an organization has been established in the American Dairy Cattle Club by Mr. E. Parmlee Prentiss.

When a new breed is presented for recognition by this Society the following tentative standard procedure is recommended before recognition is granted by adding the name of the breed to our approved list:

1. A complete statement of the facts relative to the origin of the proposed new breed.
2. The animals have certain distinguishing characteristics common to all animals of the group, these characteristics being so firmly fixed as to be transmitted from parents to offspring with reasonable uniformity.
3. They must have some importance to the livestock industry and be available in sufficient numbers to give a sound basis for perpetuation and improvement.
4. A standard of perfection for the breed has been established with concise statements on which the sponsors justify the breed.
5. Progress in the development of a type or performance to a point where it merits recognition as a definite breeding group.
6. An organization has been established for conducting the affairs of the breed. This is one of the first evidences of good faith and careful direction of effort.
7. Rules and regulations for recording and transfer of animals have been established.
8. Provision for the maintenance of records thereof have been made.
9. Maintaining of records in some permanent form and available to the public such as published records, keeping microfilms of each registry card, etc.
10. Encouragement should be given for basing registration not on pedigree alone but to include some phases of progeny testing.
11. Finally a favorable report or the contrary would be presented by your committee to the Society which would adopt or reject the recommendation.

It will obviously be necessary for the Association to have an approved list of breeds if additions are to be made thereto. In this connection it may be necessary to make a definite distinction between the recognition of breeds and the recognition of pedigree registry associations. Recognition of breeds is less complicated and this might be tried out first and be well established before attempting to deal with the recognition of breed associations.

At the 1941 meeting the Society approved the report of this committee which states "That the two organizations set up to record the pedigrees of Tennessee Walking Horses and Quarter Horses be added to the list of breed associations already generally recognized."

Since this meeting the Committee's attention has been called to the fact that the Society has no such list to which these breeds could be added. It may be that a strict interpretation of the constitution would render the 1941 action not final until approved a second time at a subsequent meeting.

Under date of December 22, 1941, one of our members, R. B. Cooley, representing the National Association of Stallion Registration Boards, has submitted through President Bethke, for consideration by this Committee, eight other newly organized horse pedigree registry associations, each representing a new breed of horses. It is recommended that no action be taken at this meeting on this request.

The following constitutes the list of breeds of our domestic farm animals tentatively proposed by this committee:

Cattle	*Swine*	*Sheep*
Aberdeen-Angus	Berkshire	Cheviot
Ayrshire	Chester White	Corriedale
Brown Swiss	Duroc-Jersey	Cottswold
Devon	Hampshire	Dorset
Guernsey	Poland China	Hampshire
Hereford	Spotted Poland China	Lincoln
Holstein-Friesian	Tamworth	Merino
Jersey	Yorkshire	Oxford Down
Red Polled		Rambouillet
Shorthorn		Romney
		Shropshire
		Southdown
		Suffolk

Horses	*Jack Stock*	*Fur Sheep*
American Saddle	American	Karakul
Arabian		
Belgian		
Cleveland Bay		
Clydesdale		*Goats*
Hackney		Alpine
Morgan		Angora
Percheron		Nubian
Quarter Horse		Saanen
Shetland (pony)		Toggenburg
Shire		
Standardbred		
Suffolk		
Tennessee Walking Horse		
Thoroughbred		
Welsh (pony)		

The Special Committee on Show-Ring Standards made recommendations aimed to stimulate progress in bringing about desirable changes in show-ring standards and practices. The report was accepted and placed on file as a basis of reference for the work of future committees.

The proposed revised constitution as amended was adopted and is printed in full immediately following this summary.

Included in the report received from the Resolutions Committee was a statement of "necessities of the existing agricultural situation for consideration in relation to the attainment of the Government goals for increased livestock products."

Recommendations of the Executive Committee given unanimous approval were (1) that a Special Committee on Necrology be appointed and the extent of the material published be left to the discretion of the Editorial Board; (2) that the Secretary-Treasurer be instructed to invest $2,000 of

the Society's funds in War Bonds, and (3) that a registration fee of 50 cents per person be charged at the next annual meeting.

President Bethke announced that Dr. Ralph G. Schott has been named by the Executive Committee to serve as acting Editor of the JOURNAL OF ANIMAL SCIENCE while Dr. Ralph W. Phillips is on leave because of foreign service.

Unanimous votes of appreciation were extended to the Editorial Board for its outstanding accomplishments during the past year with the JOURNAL OF ANIMAL SCIENCE, and to the Executive Committee for the excellent financial condition of the Society.

The following officers were elected for 1943:

President—L. A. Maynard
Vice-President—L. A. Weaver
Secretary,
Treasurer—A. D. Weber

CONSTITUTION OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

ARTICLE I—THE SOCIETY AND ITS PURPOSES

Section 1. Name

This association shall be known as the American Society of Animal Production.

Section 2. Object

The object of the Society shall be (a) to afford opportunity for the exchange of ideas in the field of interest of the Society, (b) to bring about improvement and unification of methods of investigation, instruction, and extension in animal production, (c) to arrange for desirable cooperation and for the avoidance of undesirable duplication in investigational work, (d) to make recommendations relative to the adoption of new practices, and (e) to publish educational and scientific material of value to members and other workers in the animal industry field, in its official organ of publication, the JOURNAL OF ANIMAL SCIENCE.

ARTICLE II—MEMBERSHIP

Section 1. Eligibility

All persons engaged or previously engaged in investigation, instruction, or extension in animal production or in the production of livestock or livestock products shall be eligible for membership.

Section 2. Nomination and Election

Membership may be obtained after formal application sponsored by not less than two members of the Society in good standing, the payment of dues, and election by the membership committee.

Section 3. Dues and Subscriptions

The membership dues include a subscription to the JOURNAL OF ANIMAL SCIENCE, and their amount shall be fixed by the executive committee advising with the editorial board of the Journal. The dues and subscription rate may or may not be identical in amount, but a new subscriber does not automatically become a member.

Section 4. Forfeiture

A membership or subscription is void if not paid by January 1 of the calendar year to which it applies. Reinstatement of membership forfeited because of failure to pay dues takes place automatically as soon as delinquent dues are paid.

ARTICLE III—OFFICIALS

Section 1. Officers

The officers of the Society shall consist of a president, vice-president, sectional vice-presidents, and a secretary-treasurer. These with the outgoing president and the editor of the JOURNAL OF ANIMAL SCIENCE shall constitute the executive committee.

Section 2. Term of Office

The president and vice-president shall hold office for one year, the vice-president normally succeeding the president at the end of the regular year in office. The secretary-treasurer shall hold office for not less than three years. In the absence of other provisions for succession, all officers shall serve until their successors are duly elected.

Section 3. General Duties

The president, vice-president, sectional vice-presidents, and secretary-treasurer shall perform the duties usually incumbent upon those officers. In questions of parliamentary procedure, the provisions of Roberts' Rules of Order shall apply. The executive committee shall conduct the business of the Society in the intervals between the meetings.

ARTICLE IV—ELECTION OF OFFICERS

Section 1. Procedure

The election of officers shall be held at the annual meeting of the Society. A nominating committee shall have been appointed by the president and

shall have nominated not less than two candidates for vice-president, and, before expiration of the three-year term of office, not less than two candidates for secretary-treasurer. When the secretary-treasurer after his term of office normally is to succeed to the vice-presidency, the committee may put only his name in nomination. The slate of nominees shall be published in the current year's November issue of the JOURNAL OF ANIMAL SCIENCE. Additional nominations may be made from the floor at all annual meetings. Election shall be by ballot. A majority of the votes shall be required for election. In case an annual meeting is not held, election shall be by mail.

Section 2. Filling Vacancies

The executive committee shall fill, for the unexpired term, all vacancies in elective positions. The President of the Society shall fill all vacancies in appointive positions.

ARTICLE V—MEETINGS

Section 1. General Society Meetings

The Society shall hold an annual meeting at a time and place to be selected by the executive committee, which shall be responsible for a program and shall make other necessary arrangements for the meeting. The executive committee shall have the authority to cancel an annual meeting if circumstances make such action necessary or desirable.

Section 2. Sectional Meetings

Sectional meetings shall be held at times and places set by the officers of the several geographical sections.

ARTICLE VI—COMMITTEES

Section 1. Standing and Special Committees

The special work of the Society shall be conducted through five standing committees—a committee on investigation, a committee on instruction, a committee on extension, a committee on membership, an editorial board for the JOURNAL OF ANIMAL SCIENCE—and through such special committees as may be authorized by the Society or by the executive committee. Final adoption of a recommendation of the committees of the Society may be deferred until a subsequent meeting.

Section 2. Committee Personnel

The standing committees shall consist of not less than five members, the editorial board not less than eight in addition to the editor, who shall be chairman, and the business manager, and shall be appointed by the executive committee within two weeks following the annual meeting of the Society.

The executive committee shall at the time of appointment designate the chairman of the committees that have no permanent chairman.

Section 3. Committee Tenure

All committees except the editorial board shall serve for one year, but this provision shall not deprive the executive committee of the power or right to reappoint the same personnel or any part thereof of any standing or special committee. The editorial board for sake of continuity shall have only part of its membership retire each year.

Section 4. Committee on Investigation

It shall be the duty of the committee on investigation to consider matters within the field of investigation and to present at the annual meeting of the Society, statements of work accomplished and recommendations for consideration or adoption by the Society.

Section 5. Committee on Instruction

It shall be the duty of the committee on instruction to consider matters within the field of instruction and to present at the annual meeting of the Society, statements of work accomplished and recommendations for consideration or adoption by the Society.

Section 6. Committee on Extension

It shall be the duty of the committee on extension to consider matters within the field of extension and to present at the annual meeting of the Society, statements of work accomplished and recommendations for consideration or adoption by the Society.

Section 7. Committee on Membership

It shall be the duty of the committee on membership to determine that candidates for membership meet the requirements set forth in Article II, Section 1, before they are elected. It shall be the further duty of this committee to plan the membership structure and make constant effort to maintain and increase membership. The president shall be a member of this committee.

Section 8. Editorial Board of the Journal of Animal Science

It shall be the duty of the editorial board, subject to review by the executive committee and the Society, to determine policies and procedures in regard to publishing the JOURNAL OF ANIMAL SCIENCE. The executive committee advising with the editorial board shall appoint the editor, and may appoint a business manager, for an indefinite period, but their terms of office may be terminated at any time at the pleasure of the Society.

ARTICLE VII—CHANGES IN CONSTITUTION

Section 1. Procedure for Amending the Constitution

A proposed amendment to the constitution must be signed by at least three members and may be considered and adopted at any regular meeting of the Society, only provided that notice of such amendment reaches the secretary at least sixty days prior to the meeting, and further that through the JOURNAL OF ANIMAL SCIENCE, or otherwise, notice of such amendment reaches the members at least thirty days prior to the meeting. A vote of two-thirds of the total number cast shall be required for the adoption of an amendment.

CHAIRMEN OF COMMITTEES FOR 1943

Committee on Investigation . . . . . W. E. Krauss (Ohio)
Committee on Instruction . . . . . F. L. Bentley (Pennsylvania)
Committee on Extension . . . . . H. G. Zavoral (Minnesota)
Committee on Membership . . . . . L. A. Weaver (Missouri)
Special Committee on Information . . . . . R. C. Pollock (Nat'l. Livestock and Meat Board, Chicago)
Special Committee on Cooperative Meat Investigations . . . . . R. S. Glasscock (Florida)
Special Committee on Pasture and Range Investigations . . . . . R. H. Lush (Nat'l. Fertilizer Assoc., Washington, D. C.)
Special Committee on Evaluation of Feeds . . . . . E. W. Crampton (Macdonald College, Quebec)
Special Committee on Artificial Insemination and Recognition of New Breeds . . . . . G. H. Hart (California)
Special Committee on Necrology . . . . . C. W. McCampbell (Kansas)
Representative on National Research Council. H. W. Marston (U.S.D.A)

MEMORIAL

J. A. McLEAN

J. A. McLean, Educational Director for the Quaker Oats Company, died at his home in Hollywood, California on April 28, 1942, after a year's illness. He was born in Ormond, Ontario on May 16, 1878, and married Margaret Pendergrast, who survives him, in 1907. He received the B.A. degree from McMaster University (Toronto) in 1902 and the B.S.A. from Iowa State College in 1905. From 1906 to 1908 he was associate professor of animal husbandry at Iowa, from 1908 to 1910 was animal husbandman at the Mississippi Experiment Station, and from 1911 to 1916 was professor of animal husbandry at Massachusetts Agricultural College. In 1916 he went to the University of British Columbia to organize the Department of Animal Husbandry in the newly established Faculty of Agriculture, and remained there until 1920, when he went with the Quaker Oats Co. He was well known in livestock circles and his kindly smile, his gracious manner and his helpful advice will be missed by many.

NEWS AND NOTES

Ralph W. Phillips, senior animal husbandman in charge of genetics investigations in the Bureau of Animal Industry and editor of the JOURNAL OF ANIMAL SCIENCE, is on leave from the Bureau for a year and will be employed during that time by the Department of State. He will serve as consulstant in animal breeding to the Chinese Government. During his absence, Ralph G. Schott of the Animal Husbandry Division, Bureau of Animal Industry, Beltsville, Maryland, will serve as acting editor of the Journal.

A new text entitled "Introduction to Breeding Farm Animals" by L. M. Winters was published recently by John Wiley and Sons, Inc., New York, N. Y. It is designed for use by students in secondary schools and by breeders who have not had formal training in genetics and physiology of reproduction.

R. G. Johnson of Oregon State College is on leave for a year, and will act as advisor on animal production problems to the Chinese government, under auspices of the State Department.

George K. Davis, formerly research assistant in chemistry at Michigan State College, is now nutrition technologist in the animal industry department at the University of Florida in Gainesville.

J. L. Krider recently received the Ph.D. degree at Cornell University and is now working in the swine division of the animal husbandry department, University of Illinois.

G. K. L. Unterbjerg, formerly of the University of Nebraska, is now located at the Veterinary Research Institute, Iowa State College.

L. E. Harris, formerly of the University of Arkansas, is now agent for the Department of Interior's Fish and Wildlife Service, and is located at the Animal Nutrition Laboratory, Cornell University.

R. A. Rasmussen, formerly assistant professor of animal husbandry at the Utah State Agricultural College, is now associate chemist at the Michigan Agricultural Experiment Station.

E. B. Bertone, formerly junior animal fiber technologist with tne Bureau of Animal Industry has accepted a position in the animal husbandry department at Colorado State College where he will be responsible for the work of the wool scouring laboratory as well as other phases of the wool work.

W. H. Wiley, assistant in animal husbandry, Arkansas Agricultural Experiment Station, has entered military service.

W. L. Wright of the Kentucky Experiment Station staff has resigned to operate a farm in Wisconsin.

Walter Garth, Jr., of Sanford, Maine, has been appointed specialist in mohair and wool marketing by the Texas A. & M. College Extension Service.

C. F. Winchester, instructor in animal husbandry (Coop. U.S.D.A.), Missouri Experiment Station, has entered military service.

A. E. Darlow, head of the animal husbandry department, University of Wisconsin, has resigned, effective January 15, to return to Oklahoma A. & M. College where he will be head of the animal husbandry department, replacing W. L. Blizzard who is now dean and director.